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PART I

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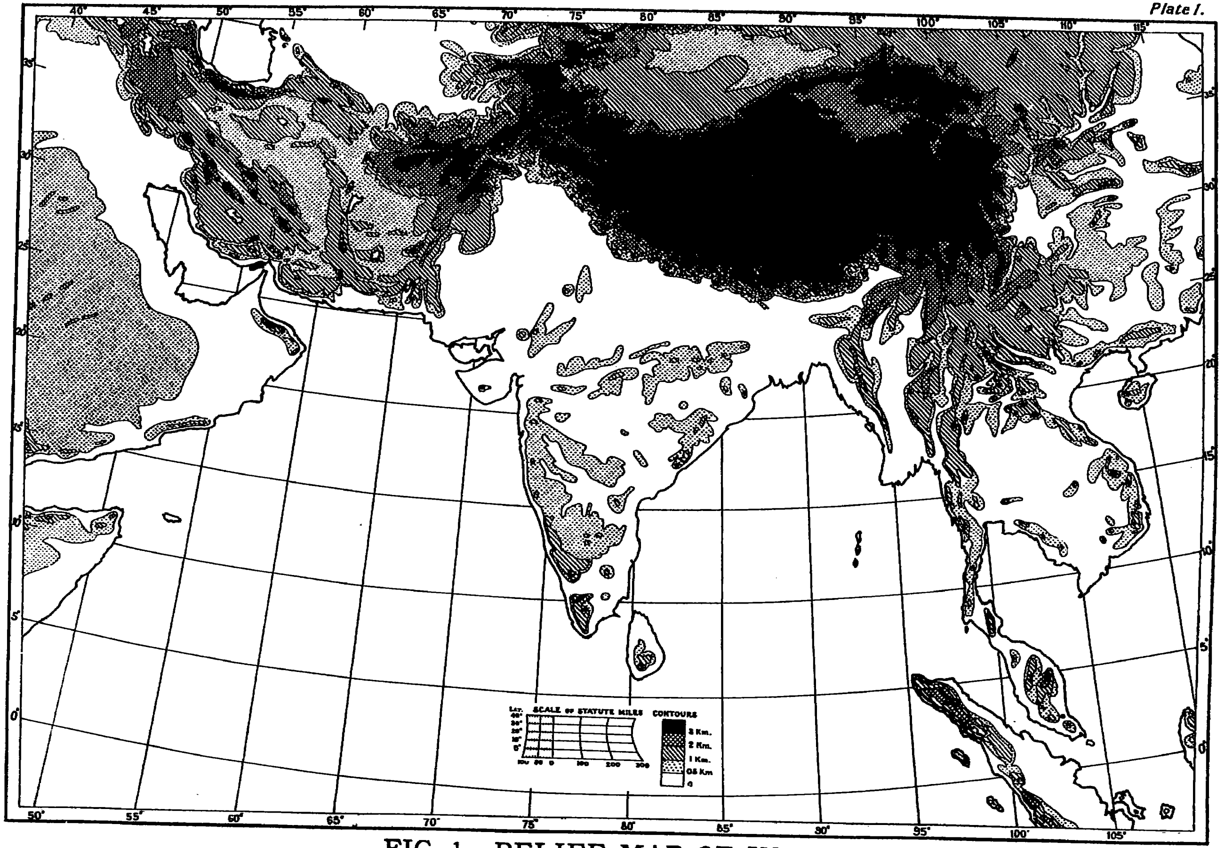

FIG. 1. RELIEF MAP OF INDIA

G.P.Z.O. Poona, 1935.

INDIA

METEOROLOGICAL DEPARTMENT

METEOROLOGY

FOR

AIRMEN IN INDIA

PART I.

GENERAL METEOROLOGICAL FEATURES

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
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1936.

FOREWORD.

The demand frequently made by airmen and others interested in flying for information about weather conditions along the various air routes has led to the preparation of this handbook. The aids which pilots can obtain day by day from the India Meteorological Department in the form of forecasts, upper wind reports and current weather reports have been fully explained in the pamphlet on "Meteorological Organisation for Airmen", issued separately. To obtain the full benefit of the weather forecasts and other reports which are made available by the Department to airmen in respect of any particular air-route, it is desirable that they should have a general knowledge of the kind of weather likely to be experienced under the normal conditions prevailing in any season. It is not possible in this small handbook, which has been compiled in this Department, to explain all the details of weather over any air-route, but it is considered that the materials herein presented will be found useful by all airmen, whether flying regularly or only planning an occasional flight over the Indian air routes.

This book is published in two parts. Part I gives an account of the general meteorological features over the country which are of interest to airmen, and Part II the climatological notes in respect of the different air routes.

Pilots of sea-planes may supplement the information given in this book by a reference to the publication of the India Meteorological Department entitled, "Winds, Weather and Currents on the Coasts of India and the Laws of Storms."

Suggestions for increasing the usefulness of this handbook in future editions will be welcomed.

POONA;

March 16, 1935.

C. W. B. NORMAND,

Director-General of Observatories.

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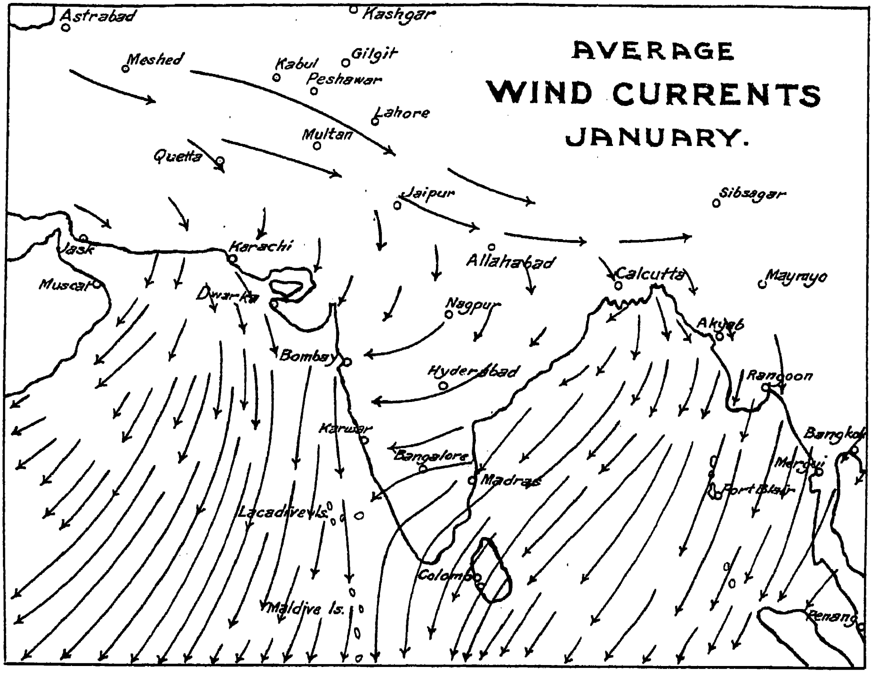

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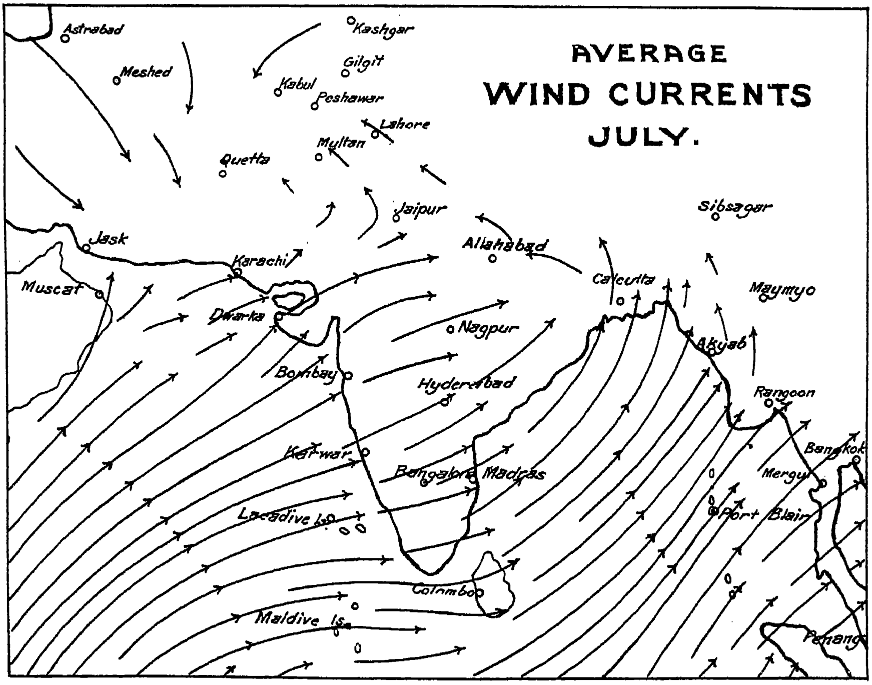


FIG. 3

G.P.Z.O. POONA, 1935.

CHAPTER 1.

THE MONSOONS AND THE SEASONAL DISTRIBUTION OF WINDS, TEMPERATURE, PRESSURE AND AIR DENSITY.

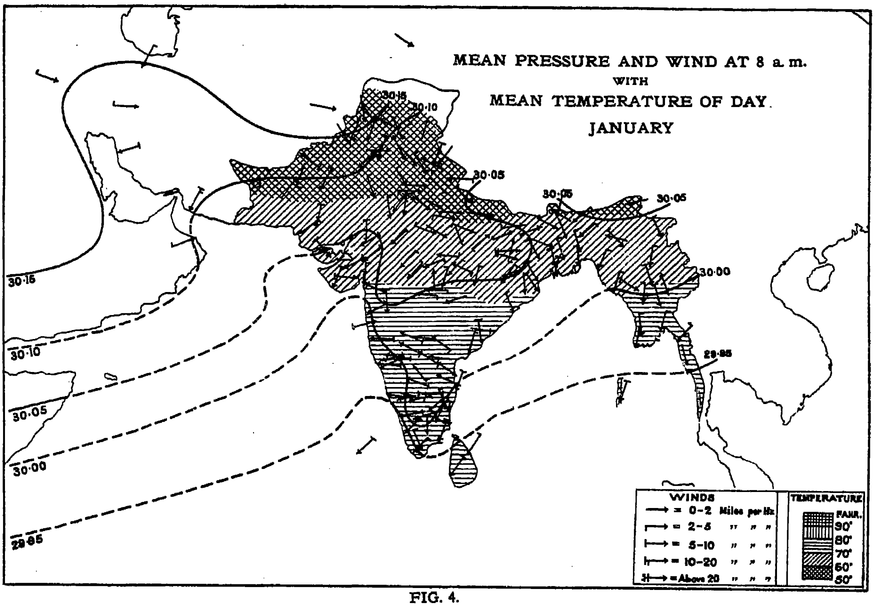
Contrasts and seasons.—India presents as great contrasts in meteorological conditions as any area of similar size in the world, and furnishes the typical large scale example of the alternation of seasons known as monsoons. The contrasts are striking.

In the north-west lies the great Thar desert with average annual rainfall of less than 5 inches ; in the north-east is Cherrapunji with an average annual rainfall of 424 inches. The observatory at Dras in Kashmir has recorded a temperature as low as —49°F.; that at Jacobabad has several times registered 126°F. and over. Hill stations in the Himalayas, such as Simla, may be shrouded in cloud for days together in August and September with humidities of 100 per cent., but in December may be overrun with air of very nearly zero humidity. The mean *annual* range of temperature at Cochin in South India, 20°F., is less than the *daily* range at many stations in North India and only about one-third of their annual range. During the winter third of the year the general flow of the surface air strata is from land to sea and thence over the Indian Seas as a *north-east monsoon* (Fig. 2) ; it is a season of winds of continental origin and great dryness. The summer third of the year sees a complete reversal of this condition in a flow from sea to land of the moist winds of the *south-west monsoon* (Fig. 3) ; this consequently is a season of much humidity and cloud and frequent rain. Between these principal seasons of the year are the transitional periods of the *hot weather* months, April and May, and of the *retreating south-west monsoon*, October and November. The causes determining the monsoon currents are many and complex, but the fundamental cause is certainly the difference of temperature in the winter and summer months respectively between southern Asia on the one hand and the Indian Ocean and China Seas on the other.

The North-east monsoon is fully established in the Indian land and sea areas in the beginning of January (*Fig. 4*), when temperature is lowest in the Asiatic continent. There is then a belt of high pressure with anti-cyclonic conditions stretching from the west Mediterranean to central Asia and north-east China. Clear skies, fine weather , low humidity, large diurnal range of temperature, and light northerly winds are the usual feature of the weather in India during this period, broken only at intervals by weather disturbances which pass eastwards across Persia and Northern India, often into China. These disturbances are ordinarily less intense than, but similar in type to, the depressions of European latitudes. The precipitation accompanying them is small in amount, but very important for the winter crops. Some in their eastward passage give light rains over the whole of Northern India, while others which confine their activity to the extreme north give moderate to heavy rain in the Punjab plains and Kashmir and heavy snowfall in the higher Himalayas. The disturbances are attended with marked temperature effects, a rise occurring in front of them while in the rear unusually dry clear weather prevails, as a rule with stronger and cooler westerly winds. During this period of the year, rainfall is greatest in the north-west and decreases towards the south and east; dry weather prevails generally in the Peninsula and south Burma. The distribution of temperature is almost similar to that of rainfall, weather being colder in the north-west than in the east and south.

The Hot weather period of March to May (*Fig. 5*) is one of continuous increase of temperature and decrease of barometric pressure in north India, of continuous decrease of temperature in the south Indian Ocean and adjacent land areas of Africa and Australia and of intensification of the southern anticyclonic high pressure area. There occurs a steady transference northward of the area of greatest heat in India, and simultaneously of the equatorial belt of low pressure of the winter season. In March the highest day temperatures, about 100°F., occur in the Deccan; in April the area of highest day temperatures, from 100° to 110°F., lies over the south of the Central Provinces and Gujarat; while in May the seat of greatest heat is northern India, and especially the north-west desert, where day temperatures of 120°F. or over are not infrequent. The area of lowest pressure also lies then over north-west India, with a trough stretching thence to Chota Nagpur. A local air circulation, with this trough as centre, exists over India and causes in-draughts from the adjacent seas of southerly winds across the Bengal coast and of north-westerly winds across the Bombay coast. The land and sea winds give rise to large contrasts of temperature and humidity and consequently to violent local storms, especially in Bengal, where they are usually called " Nor' westers ". These are sometimes of tornadic intensity and very destructive. During this period dust storms and dust-raising winds are more common in north India than in othar parts.

The South-west monsoon.—Towards the end of May the air circulation over India becomes more and more vigorous, until, almost abruptly, the south-east trade winds from south of the equator are induced northwards into the Arabian Sea and Bay of Bengal and caught up in the Indian circulation. In most years this relatively cool as well as humid current, known as the *south-west monsoon*, bursts on the Malabar coast during the first five days of June. It gradually extends northwards and is usually established over most of the Indian area by the end of June. (*Fig. 6*). It is the great rain-bearing current for most of India. The orographical features of India are of great importance in modifying the flow of the monsoon currents and the distribution of monsoon rainfall. The mountain ranges to the east and north of India are equivalent to two sides of a box, through the other two sides of which the monsoon currents stream. The southerly or Bay of Bengal current is naturally deflected by the two sides of the box northwards through Burma, and then westwards up the Gangetic Plain. The Arabian Sea current surmounts the Ghats on the west coast, causes copious rain there, advances over the Deccan and Central Provinces, and generally meets the Bay of Bengal current along the line of the trough of low pressure, which normally extends from Orissa to north-west India. Depressions which both intensify the monsoon rainfall and tend to concentrate it in their vicinity occasionally form in the north of the Bay and move along this trough. Further, the trough is not stationary but moves north or south of the normal position and affects the rainfall distribution as it moves. Consequently the monsoon period is not one of continuous rain in any part of India. Bursts of general rain alternate with breaks, Partially or generally as the case may be. The pulsatory character of this



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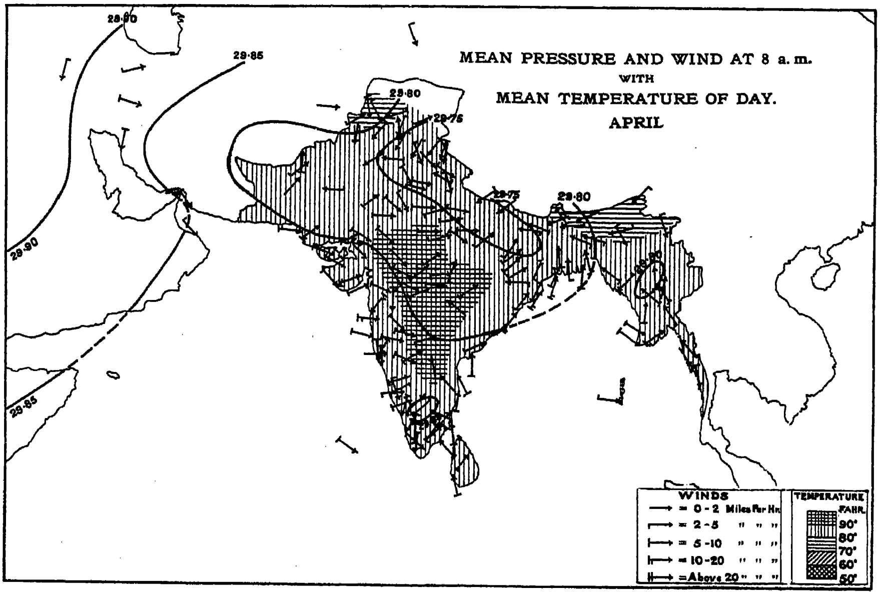

FIG. 5.

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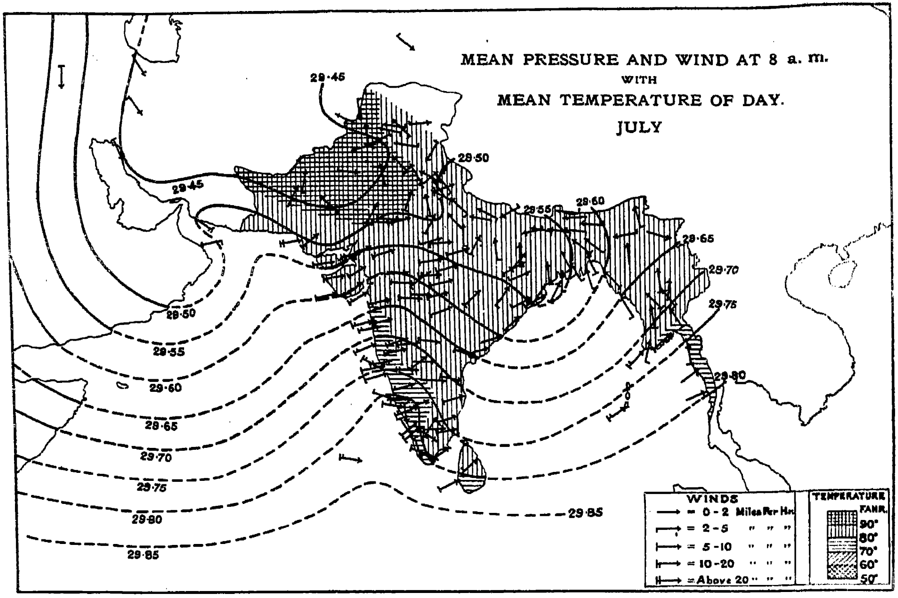

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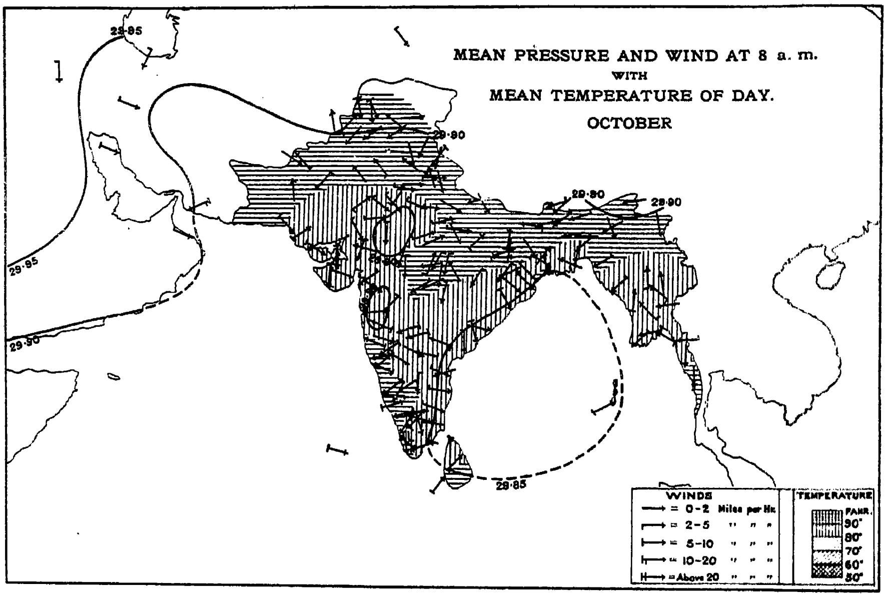

FIG. 7.

G.P.Z.O. Poona, 1936.

action and of the rainfall precipitation is one of the most important features of the monsoon period meteorologically, as it is also economically for the proper growth of the crops. On the average, it may be said that the strength of the currents and the accompanying rainfall increase from June to July and remains steady till about the end of August. The monsoon then begins to retreat from northern India. The table below shows the general distribution of rainfall month by month from May to October over the Indian land area :—

	Inches.
May	3·1
June	7·9
July	11·2
August	10·3
September	7·0
October	3·3
Total	42·8

There are four important variations from the normal in the monsoon rain over the country ; firstly, the commencement of rains may be considerably delayed over the whole or a large part of India ; secondly, there may be a prolonged break or breaks lasting over the greater part of July or August ; thirdly, the rains may terminate considerably earlier than usual ; and lastly the rains may be determined more largely than usual towards one part of the country than towards another. The last one constitutes the most common abnormality.

The retreating south-west monsoon.—The end of the wet season forms a transition period leading up to the establishment of the conditions of the dry winter season. This transition begins in the early part of October (*Fig. 7*) and is usually not completed until mid-December. The Arabian Sea monsoon current retreats southwards from Rajputana, Gujarat and the Deccan by a series of intermittent actions. The Bay of Bengal current retreats similarly down the Gangetic Plain. The low presssure conditions previously prevailing in north India are obliterated by October, and are transferred to the centre of the Bay at the beginning of November and to the south of the Bay by the beginning of December. By the end of that month the belt of low pressure usually passes out of the Bay limits into the equatorial belt, where it forms a permanent feature of the meteorology of the Indian Ocean during the next three months. Similar conditions obtain in the Arabian Sea also. This retreat is associated with dry weather in northern India but with more or less general rain on the Madras coast districts and over the eastern half of the Peninsula, where October and November are often the rainiest months of the year.

Rainfall variations.—From the foregoing description as well as from *Table 1* below, it will be understood that the distribution of rainfall over India depends largely on its orographical features. If the hills and mountains of India were effaced, the country would receive much less rainfall. It will also be seen that the rainiest season in most provinces is the monsoon period, June to September ; that rainfall during the cold weather is scanty, and that the important rains in south-east Madras are those of October to December. Stress has also been laid on the great variability of monsoon rainfall in time and space in any one year. The variations in the amount of precipitation received from year to year are also surprisingly large. The annual rainfall of the Indian region, excluding Burma, is 42 inches and variations from this normal as great as + 12 inches and — 8 inches occurred in 1917 and 1899 respectively. Long breaks in the monsoon, or an abrupt termination of rains, is disastrous to crops and produces droughts or famines.

TABLE 1.

MONTHLY AND ANNUAL NORMAL RAINFALL BY DIVISIONS.

Division.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Lower Burma	0·12	0·23	0·55	1·42	12·30	25·79	29·77	27·50	17·61	7·85	2·71	0·54	126·39
Upper Burma	0·10	0·21	0·42	1·29	5·98	8·11	7·35	8·63	8·03	5·55	1·82	0·47	47·96
Assam	0·67	1·53	4·00	9·00	12·08	18·23	18·74	16·83	12·50	5·66	0·90	0·35	100·49
Bengal	0·34	0·95	1·67	3·25	7·64	14·62	15·14	14·26	10·89	5·08	0·79	0·16	74·79
Orissa	0·44	1·17	1·08	1·38	3·31	9·83	13·01	13·00	8·96	4·88	1·52	0·22	58·80
Chota Nagpur	0·77	1·15	0·93	0·70	2·13	8·97	12·91	13·77	8·10	2·92	0·39	0·14	52·88
Bihar	0·42	0·69	0·47	0·60	2·27	7·78	12·36	12·51	8·80	2·32	0·29	0·09	48·60
United Provinces, East	0·63	0·55	0·32	0·19	0·67	4·78	11·55	11·33	6·87	1·87	0·19	0·22	39·17
United Provinces, West	0·96	0·89	0.61	0·30	0·68	4·06	11·47	11.14	5·96	0·88	0·15	0·36	37·46
Punjab, East and North	1·21	1·02	0.91	0·56	0·62	2·02	6·22	6.37	3·30	0·38	0·13	0·44	23·18
Punjab, South-West	0·50	0·53	0.64	0·52	0·42	0·81	2·47	2.56	1·11	0·10	0·08	0·21	9·95
Kashmir	3·71	3·54	4.60	3·45	1·93	2·53	7·26	7.86	3·60	1·05	0·48	1·97	41·98
N.-W. Frontier Province	1·28	1·19	1·89	1·54	0·77	0·86	2·58	3·16	1·18	0·33	0·28	0·54	15·60
Baluchistan	1·18	1·19	1·24	0·68	0·27	0·30	0·98	1·00	0·25	0·15	0·26	0·62	8·12
Sind	0·11	0·18	0·18	0·10	0·25	0·34	1·64	2·20	0·96	0·14	0·02	0·07	6·19
Rajputana, West	0·19	0·23	0·18	0·16	0·44	1·31	3·43	4·07	2·04	0·32	0·08	0·10	12·55
Rajputana, East	0·37	0·31	0·24	0·17	0·52	2·62	8·31	8·14	3·96	0·52	0·16	0·22	25·54
Gujarat	0·09	0·10	0·07	0·03	0·33	5·15	12·61	8·11	4·64	0·91	0·20	0·04	32·28
Central India, West	0·38	0·30	0·16	0·15	0·47	4·78	10·52	10·97	5·21	0·80	0·41	0·16	34·31
Central India, East	0·56	0·63	0·33	0·22	0·43	4·50	12·04	12·49	6·36	1·17	0·35	0·21	39·29
Berar	0·39	0·35	0·33	0·24	0·54	6·05	9·12	6·91	5·80	1·57	0·57	0·39	32·26
Central Provinces, West	0·65	0·71	0·59	0·31	0·59	7·39	13·44	12·91	7·60	1·82	0·56	0·30	46·87
Central Provinces, East	0·46	1·11	0·60	0·73	0·79	9·32	15·27	14·93	7·59	2·25	0·40	0·29	53·74
Konkan	0·10	0·05	0·06	0·36	1·55	25·31	39·09	23·99	12·53	4·30	1·01	0·13	108·48
Bombay Deccan	0·15	0·08	0·15	0·63	1·35	5·22	7·85	5·44	5·61	3·02	1·01	0·28	30·79
Hyderabad, North	0·16	0·25	0·37	0·51	0·73	5·51	8·00	7·23	8·10	2·30	0·77	0·36	34·29
Hyderabad, South	0·18	0·24	0·42	0·81	1·02	4·33	6·24	6·31	6·82	3·02	1·06	0·22	30·67
Mysore	0·12	0·13	0·31	1·46	3·58	4·80	7·15	5·23	5·18	5·30	2·42	0·45	36·13
Malabar	0·92	0·57	1·50	3·84	7·39	23·82	21·50	12·16	7·85	11·33	7·36	1·86	100·10
Madras, South-East	0·98	0·47	0·51	1·29	2·53	1·56	2·19	3·61	4·48	7·10	7·47	3·38	35·57
Madras, Deccan	0·20	0·14	0·21	0·62	1·67	2·36	3·21	3·91	5·75	4·18	2·18	0·41	24·84
Madras Coast, North	0·38	0·39	0·50	0·93	2·10	4·91	6·61	7·07	6·96	6·75	3·69	0·85	41·14

On the other hand, tracts of country are sometimes deluged with rain and suffer distress through excessive flooding. These heavy downpours occur chiefly near the tracks of the cyclonic depressions of the monsoon months or of the cyclones that occasionally advance inland from the Bay of Bengal or Arabian Sea. A fall of 10 inches to 20 inches in a day is by no means a rare occurrence. The heaviest ever recorded in the plains in 24 hours is 35 inches at Purnea in Bihar.

Cyclones.—At a time when the general meteorology of India was unknown, Henry Piddington laid the foundations of our knowledge of the storms of the Indian Seas and introduced the word *cyclones* to connote them. In these storms, oval or circular in shape, the air moves in converging spirals in a left-handed direction against the hands of a clock. The winds become fiercer and fiercer as the centre is approached and reach hurricane force near it. In the innermost central zone of some ten miles diameter the wind suddenly falls off to a calm or light air, and the barometric pressure there often marks an inch, and sometimes as much as two inches, below normal. Cyclones generally die away soon after they reach land, but in the coastal districts which they touch may cause great havoc through high winds, torrential rain and, most destructive of all in low-lying districts, storm waves. The latter are due to the huge masses of sea water swept forward by the storms and, when aided by a high tide, may inundate low-lying land to a depth of 20 feet. The storm wave accompanying the Bakarganj cyclone of 1876 was one of the most destructive on record; about a hundred thousand people were drowned in half-an-hour on the alluvial flats of the Meghna, while an equal number died from the epidemics of fever, cholera and other diseases which almost invariably follow a storm wave. The principal cyclone months in both the Arabian Sea and Bay of Bengal are May, October and November. They may also occur in April, September and December, and, particularly in the Arabian Sea, in June, on the advancing front of monsoon air.

Temperature and climates.—During one part of the year, from January to May or June, the increase of temperature by solar action is greater than the loss by radiation and other actions, and hence temperature rises more or less steadily in conformity with the increasing elevation of the sun. During the remainder of the year, the balance is the other way and temperature steadily decreases from June or July to December. Though in most countries July and August are as hot as, or hotter than June, the similar phenomenon is prevented in India by the cloud and rains of the south-west monsoon. The annual variation of temperature is small in the extreme south and increases rather rapidly northwards; proceeding along the east and west coasts of India, it is twice as great at Bombay and Rangoon as in Malabar and over four times as great at Karachi. It is from eight to ten times as great at stations in the north Deccan and northern and central India and is absolutely greatest in the most inland of the driest tracts, including Upper Sind and the Punjab. The difference between the minimum and maximum temperatures on a day, called the diurnal range, is much smaller in the wet than in the dry season and at coast stations than in the interior. It is about 12°F. on the west coast of the Peninsula, and rises to 30°F. on the mean of the year in the Punjab and Upper Sind.

As already indicated, different parts of India exhibit very great diversity in respect of their climatic features. Northern or extra-tropical India alone, in its most easterly and most westerly provinces, in Assam on the one hand and in Sind on the other, presents us with the greatest possible contrast of dampness and dryness, a contrast greater than that of the British Isles and Egypt;

and when further we compare the most northerly province, the Punjab, with the most southerly, such as Travancore or Tenasserim, we find in the former a continental climate of the most pronounced character, extreme summer heat alternating with winter cold that sometimes sinks to freezing point, and in the latter an almost unvarying warmth in conjunction with a uniformly moist atmosphere that is especially characteristic of the shores of a tropical sea. In addition to this heterogeneity on the plains, there is a further variety due to the hills. The hill stations are situated along the Himalayas and on the Ghats in the Peninsula. In all cases their atmosphere is cooler and damper than that of the neighbouring plains; but while those in the north-west Himalayas are subject to great vicissitudes of heat and cold, dryness and dampness, in the course of the year, those of southern India and Ceylon are comparatively uniform in these respects, and their fine clear season is shorter than at the northern stations, and by no means so dry. In *Table 2* are given the temperature data for some selected stations.

Normal air density at M. S. L.—*Fig. 8* shows the distribution of normal air density in India at mean sea level in January, April, June and October. The lines of equal density or isopycnics, as they are called, have been drawn at intervals of 10 grammes per cubic metre (10 gm./m^3.) The lie of the isopycnics in each season is in general similar to that of the lines of equal pressure and temperature. In winter the air density is greater over the north than over the south. The gradient of density is largest in this season, the maximum occurring in January. During the hot weather the seat of low density lies in the centre of the country, while in the monsoon it shifts to north-west India, the lowest density in the year occurring in the month of June over Sind and Baluchistan. In October with the advent of the winter conditions the reversal takes place again, the values over northern India becoming greater than those over southern India.

Mean monthly densities in grammes per cubic metre at various heights over northern and southern India have been shewn in *Table 3*.

In order to counteract the effect of reduced air density on the take-off and landing of an aeroplane on an aerodrome where the density is appreciably below the standard density of 1226 gms. per cubic metre, it is necessary to reduce the "all-up" weight of an aeroplane. For (*a*) landing and (*b*) take-off, the approximate percentage reduction is respectively: (*a*) the same as, and (*b*) 1·15 times the percentage difference of the actual air density from the standard air density. For example in June at Peshawar, when the air density may fall as low as 1100 gms. per cubic metre, it may be necessary to reduce the "all-up" weight of an aeroplane by 10 per cent. in order to retain the same landing characteristics as on an aerodrome at sea-level with a standard atmosphere.

Plate 5.

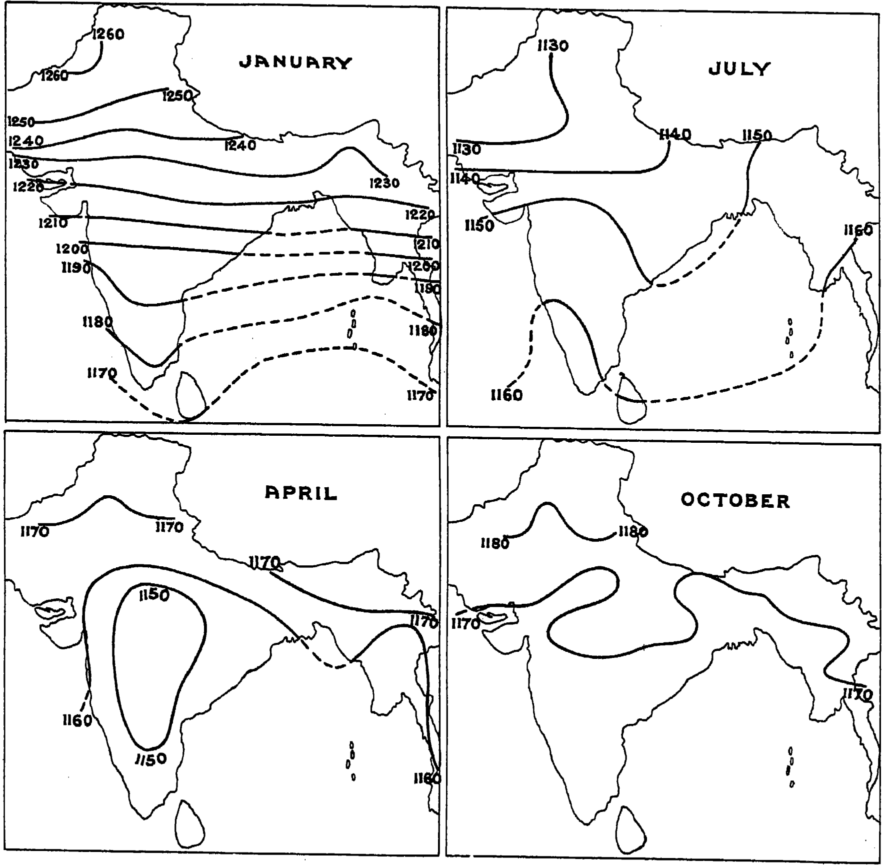

FIG. 8. AIR DENSITY AT M.S.L.— ISOPYCNICS AT INTERVALS OF 10 Gm./M^3.

G.P.Z.O. POONA, 1935.

TABLE 2.

MEAN MAXIMUM AND MINIMUM TEMPERATURES

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Highest Maximum.	Lowest Minimum.
Bahrein .	66·1 *56·4*	66·7 *57·2*	72·8 *62·9*	81·3 *70·0*	90·2 *78·0*	93·5 *83·1*	96·9 *85·1*	97·6 *85·6*	94·1 *82·0*	88·5 *76·0*	79·8 *69·0*	70·6 *60·4*	108·8	40·8
Gwador .	74·2 *59·3*	76·1 *60·6*	83·4 *66·9*	89·6 *73·5*	94·5 *78·2*	92·1 *81·0*	89·8 *80·5*	86·9 *77·4*	87·9 *74·8*	89·5 *71·4*	83·5 *64·3*	77·1 *60·7*	111·8	40·8
Karachi . (Drigh Road).	78·3 *51·2*	80·5 *54·5*	89·5 *62·1*	94·7 *71·5*	94·8 *77·5*	94·0 *82·0*	91·2 *81·1*	87·8 *78·6*	89·8 *76·2*	95·1 *68·7*	89·7 *59·2*	80·8 *52·7*	116·3	31·4
Jodhpur .	76·9 *50·5*	80·6 *53·3*	90·9 *62·7*	100·2 *72·5*	106·0 *79·8*	103·8 *82·2*	97·5 *80·3*	93·1 *77·7*	94·8 *75·5*	96·4 *67·8*	88·8 *58·6*	79·6 *52·2*	121·3	28·1
Delhi .	70·0 *47·9*	74·6 *51·7*	86·0 *61·6*	97·9 *72·8*	104·0 *80·2*	103·3 *83·6*	94·9 *81·1*	92·4 *79·8*	93·0 *77·1*	91·6 *68·4*	82·2 *56·7*	72·9 *48·9*	118·0	32·5
Agra . .	74·2 *43·8*	78·5 *46·9*	90·2 *55·8*	101·7 *67·8*	107·5 *77·0*	105·6 *83·4*	95·0 *80·2*	91·7 *78·9*	93·1 *75·6*	92·9 *62·7*	85·5 *49·5*	76·9 *44·4*	120·3	33·9
Allahabad .	74 4 *48·0*	79·5 *51·9*	91·9 *61·7*	102·8 *72·0*	106·6 *79·6*	102·1 *82·7*	92·8 *79·8*	90·0 *78·6*	91·5 *76·9*	91·1 *67·5*	83·4 *55·3*	75·7 *47·7*	119·8	34·1
Jubbulpore	77·5 *48·6*	81·5 *52·4*	91·8 *60·5*	100·8 *70·2*	105·3 *78·5*	97·8 *78·9*	86·7 *75·0*	84·6 *74·0*	87·2 *72·8*	87·7 *64·2*	82·0 *53·2*	77·0 *46·7*	114·8	31·9
Patna .	72·7 *50·9*	77·5 *54·2*	89·5 *63·9*	99·0 *73·3*	99·7 *77·7*	95·7 *79·8*	90·5 *79·8*	89·1 *79·4*	89·5 *78·8*	88·4 *72·8*	81·7 *61·0*	74·1 *51·8*	114·4	36·3
Sambalpur .	81·7 *55·1*	86·6 *59·9*	95·8 *67·1*	103·2 *75·2*	106·2 *81·1*	97·1 *80·5*	87·7 *77·3*	86·9 *77·1*	88·8 *77·0*	88·8 *71·5*	83·8 *61·8*	79·7 *53·7*	117·3	40·1
Calcutta .	77·5 *55·6*	82·3 *60·3*	91·0 *69·4*	95·5 *75·7*	94·6 *77·6*	91·3 *78·8*	88·6 *78·7*	87·8 *78·5*	88·2 *78·1*	87·4 *74·5*	82·2 *64·7*	77·0 *56·0*	108·2	44·2
Narayanganj	77·6 *55·5*	81·6 *58·8*	89·3 *68·1*	92·0 *74·0*	91·0 *75·9*	88·9 *78·1*	88·2 *78·9*	87·7 *78·9*	88·4 *78·7*	87·9 *75·3*	83·5 *66·1*	77·9 *57·2*	105·6	43·7
Tezpur .	73·6 *52·4*	76·0 *55·7*	82·6 *61·8*	83·4 *67·1*	86·9 *72·3*	88·8 *76·6*	89·2 *77·6*	89·0 *77·7*	88·6 *76·5*	85·8 *71·1*	80·5 *61·4*	74·5 *53·5*	98·1	42·8
Bhamo .	75·9 *48·8*	80·8 *52·6*	88·0 *59·5*	92·5 *66·5*	93·4 *72·1*	90·1 *74·5*	88·2 *74·9*	88·1 *75·0*	89·7 *74·1*	87·7 *69·6*	81·2 *60·0*	75·5 *51·3*	105·4	39·2
Mandalay .	84·5 *56·6*	90·3 *60·1*	98·1 *68·3*	102·4 *77·3*	99·8 *79·0*	94·8 *78·6*	94·7 *78·6*	93·2 *77·9*	93·1 *77·1*	92·0 *74·7*	87·7 *67·9*	83·5 *59·4*	113·6	45·1
Akyab .	80·8 *59·3*	84·3 *61·2*	88·5 *68·5*	91·3 *75·3*	90·5 *77·7*	86·0 *77·5*	84·6 *77·0*	84·6 *76·9*	86·4 *77·4*	87·3 *76·2*	84·7 *70·9*	80·7 *63·1*	100·1	47·3

TABLE 2—*contd.*

MEAN MAXIMUM AND MINIMUM TEMPERATURES—*contd.*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Highest Maximum.	Lowest Minimum.
Rangoon .	88·6 *64·9*	92·3 *66·5*	95·9 *71·2*	98·0 *76·1*	91·7 *77·2*	86·4 *76·4*	85·3 *75·8*	85·0 *75·8*	85·9 *76·0*	87·6 *75·8*	87·5 *72·7*	87·1 *67·4*	106·4	55·3
Tavoy .	89·3 *64·9*	91·1 *67·6*	93·1 *70·9*	93·9 *74·5*	88·9 *75·5*	84·6 *75·0*	83·3 *74·3*	82·9 *74·2*	84·2 *74·2*	87·6 *73·9*	87·9 *70·1*	87·7 *65·7*	100·2	47·7
Victoria Point	86·7 *73·4*	88·5 *74·4*	89·6 *76·1*	89·7 *77·2*	86·3 *76·1*	84·2 *75·1*	83·3 *74·9*	83·4 *74·9*	83·0 *74·2*	83·7 *74·5*	85·1 *74·5*	85·2 *73·7*	104·6	64·3
Ahmadabad	84·8 *57·7*	87·8 *59·5*	96·9 *67·2*	104·3 *74·4*	107·4 *79·2*	101·3 *80·9*	93·1 *78·5*	90·0 *76·8*	92·9 *76·1*	97·3 *72·4*	92·9 *65·5*	86·4 *59·3*	117·8	36·0
Poona .	86·1 *53·3*	90·6 *55·2*	97·1 *62·1*	101·1 *68·9*	98·8 *73·0*	89·0 *74·0*	82·8 *71·9*	81·7 *70·5*	84·6 *69·1*	89·4 *66·5*	86·5 *58·9*	84·7 *53·0*	110·0	38·8
Hyderabad (Dn). (Begumpet).	84·2 *59·9*	89·7 *64·2*	96·7 *70·1*	101·2 *76·2*	103·1 *80·0*	94·5 *76·1*	87·6 *73·3*	85·8 *72·5*	86·4 *72·3*	88·4 *69·4*	84·5 *63·2*	82·4 *58·3*	111·9	47·3
Bellary .	88·1 *61·8*	94·1 *66·1*	100·3 *72·2*	103·6 *77·2*	102·4 *77·5*	94·9 *75·9*	91·2 *74·9*	90·9 *73·8*	90·7 *72·9*	90·4 *71·2*	87·5 *66·2*	86·1 *61·5*	111·2	50·8
Bangalore .	80·8 *57·5*	86·2 *60·2*	91·1 *64·8*	93·5 *69·4*	91·7 *69·2*	84·9 *66·9*	82·2 *66·0*	82·0 *65·8*	82·3 *65·6*	82·1 *65·2*	79·8 *62·2*	78·9 *58·5*	100·8	45·8
Madras .	85·2 *67·3*	87·1 *68·0*	89·5 *71·7*	92·4 *77·1*	97·9 *80·9*	98·3 *80·6*	95·3 *78·5*	93·7 *77·2*	92·7 *76·6*	89·6 *74·6*	85·7 *71·9*	83·9 *69·3*	113·0	57·5
Waltair (Vizagapatam)	80·8 *67·9*	83·8 *71·1*	87·3 *74·7*	89·7 *78·3*	92·0 *80·8*	91·2 *80·2*	89·0 *78·6*	88·8 *78·2*	88·4 *78·1*	88·0 *76·4*	84·3 *72·7*	80·8 *68·1*	111·4	59·6
Mangalore .	89·2 *70·6*	88·6 *72·3*	90·1 *75·7*	91·7 *78·4*	91·3 *78·7*	85·3 *74·6*	83·9 *74·1*	83·7 *74·1*	84·5 *74·1*	86·1 *74·5*	88·2 *73·4*	89·3 *70·8*	100·1	59·8
Trivandrum .	84·0 *72·3*	85·6 *73·7*	87·6 *76·5*	88·0 78·2	86·7 *77·9*	83·1 *75·6*	82·2 *74·8*	82·5 *74·8*	83·1 *75·0*	83·0 *74·9*	82·8 *74·1*	83·3 72·9	93·5	63·0
Quetta .	50·1 *30·4*	52·5 *32·8*	63·1 *40·3*	73·4 *48·0*	84·7 *55·5*	92·0 *62·1*	93·7 *68·1*	91·9 *65·6*	85·8 *54·1*	74·5 *42·8*	64·1 *34·7*	54·9 *31·0*	103·9	3·0
Peshawar .	63·4 *40·8*	66·2 *43·8*	74·5 *52·1*	84·9 *60·4*	96·8 *70·2*	104·8 *77·3*	102·2 *79·8*	98·2 *78·5*	94·8 *71·4*	87·9 *60·3*	76·5 *48·9*	66·6 *40·5*	121·6	24·7
Lahore .	68·9 *40·2*	72·4 *43·8*	82·9 *52·9*	95·0 *62·8*	103·9 *71·8*	106·2 *78·7*	99·9 *79·7*	97·3 *78·4*	97·5 *72·7*	94·6 *59·2*	83·4 *46·8*	72·9 *39·8*	120·3	29·2
Rawalpindi.	62·7 *38·1*	65·1 *41·3*	75·0 *50·3*	86·3 *59·1*	97·9 *68·3*	103·6 *75·7*	97·9 *76·8*	93·9 *75·4*	93·4 *69·1*	88·8 *56·6*	77·5 *44·2*	66·8 *37·4*	118·0	23·9

TABLE 3.

MEAN MONTHLY DENSITIES OF AIR IN GRAMS PER CUBIC METRE,

Height in km.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean.
NORTHERN INDIA.													
1	1092	1081	1057	1049	1020	1011	1036	1032	1037	1048	1085	1087	1058
2	988	973	967	957	935	929	937	942	947	962	983	979	958
3	890	896	879	873	860	853	849	853	863	875	887	884	872
4	802	800	795	795	785	775	763	770	778	787	800	795	787
6	651	648	649	648	644	633	622	626	631	640	646	652	641
8	523	526	523	523	519	509	504	505	507	518	519	526	517
10	417	405	413	418	414	411	407	408	412	413	412	421	413
DECCAN.													
1	1056	1044	1043	1027	1027	1028	1045	1044	1044	1051	1047	1050	1042
2	972	960	957	944	942	947	952	953	957	963	968	971	957
3	882	877	881	869	864	861	863	867	867	873	876	881	872
4	795	796	799	795	789	780	780	785	784	787	789	791	789
6	646	647	645	650	639	638	637	635	638	642	642	644	642
8	521	519	521	521	519	516	512	514	516	518	518	520	518
10	419	416	420	420	419	416	413	415	414	417	419	419	417

CHAPTER 2.

UPPER WINDS.

The upper winds that ordinarily interest the aviator are those in the first three kilometres above sea-level. In describing the upper winds, we shall adopt the same classification into seasons as in Chapter 1, *viz.*, winter (December—February), hot season (March—May), monsoon season (June—September) and transition monsoon season (October and November). The monthly mean directions and velocities of wind at 0·5, 1, 2 and 3 km. above sea-level, the mean speeds irrespective of direction and the two or three most frequent directions of wind in the months January, April, July and November are given in *Table 4.* A brief summary of upper winds is also given in the form of diagrams (*Figs. 9—16*).

Winter (December—February).—In the typical winter month January, *Fig. 9*, the main features of the wind circulation at 0·5 and 1 km. are :—

(1) the slow drain of cold air from Persia and Baluchistan towards the neighbouring seas and from and along the Himalayas towards the head of the Bay of Bengal ;

(2) the curving of the north Indian air round the anticyclone which extends from Gujarat to Orissa ; and

(3) the addition of an easterly to north-easterly current in Tenasserim, the south of the Bay and the south of the Peninsula.

The mean as well as the most frequent direction up to 1 km. along the Persian Gulf and the Mekran Coast is westerly to north-westerly. North-easterly to south-easterly winds occur on about 25 per cent. of the occasions. The mean speed irrespective of direction is about 15—25 km./hr. With increase of height above 1 km., the easterly winds get less frequent and the mean strength of the westerly to north-westerly wind increases to 30 km./hr. at 2 km., 40 km/hr. at 3 km. and 50 km/hr. at 4 km. In the wake of western depressions, the wind velocities in the Persian Gulf, the Mekran Coast and Sind may sometimes go up to more than 80 km./hr.

From Karachi to Calcutta, along the route Karachi-Allahabad-Calcutta, the prevailing wind direction at 1 km. is also from the west or north-west and the mean wind speed 15—25 km./hr. In the region Karachi to Agra, north-easterly to easterly winds are, however, common at 0·5 and 1 km., and beyond Patna the wind tends to veer to north-northwest. At higher levels, the mean wind direction over the whole section is from west to north-west and the mean speed increases with height to 30—50 km./hr. at 3 km.

Two peculiarities of upper wind distribution in north India during the winter may be mentioned here. One is the greater tendency of southerly to south-easterly winds to occur in the south and east Punjab than at places further south or east in connection with western disturbances, and the other is the occurrence of an easterly flow of air from Assam to north Bengal down the Brahmaputra Valley. The easterly current from Assam lies below the general upper westerlies, the percentage frequencies of easterly winds at Tezpur at 0·5, 1, 2 and 3 km. being about 80, 70, 60 and 35 respectively. The easterly and westerly streams meet at the usual flying levels near about Rangpur where exceptional bumpiness may sometimes be experienced.

In the section Calcutta to Victoria Point, the principal wind direction in the lower levels is from northerly to north-westerly up to Akyab and, after passing through a region of indefinite character, changes to some easterly direction at Rangoon ; it definitely becomes easterly in Tenasserim. Southerly winds sometimes extend up the coast to Chittagong in the first 1 km. Up to Akyab the mean wind speed increases with height above 1 km., its value at Akyab being about 15 km./hr. at 1 km. and 30 km/hr. at 3 km., but at Rangoon and further south the increase is small, the mean speed at 1 and 3 km. above Rangoon being about 15 and 20 km./hr. As is evident from the charts, the winds in the south Bay of Bengal and the south of the Peninsula are generally from the east and have a mean speed of about 25 km./hr. at 1 km. There is not much change of speed with height. As we go northward, north-easterly winds become more common on the eastern side of the Peninsula. In the central parts of the country, the wind directions are variable, generally ranging between north-west and north-east, the north-westerlies becoming more common above 2 km.

Hot season (**March—May**).—We may take April (*Fig. 10*) as a representative month of the hot season.

The chief points of difference of the wind structure in the hot season from that in the winter arise from the fact that the anti-cyclone over Sind and Central India has weakened and is replaced by a cyclonic circulation round a low pressure area in the central parts of the country. This change, however, takes place without any large alteration in the upper circulation above 2 km.

In the Persian Gulf and along the Mekran Coast, the wind directions lie principally between west and north-west, but south-westerlies and southerlies are also common in the Persian Gulf especially at 0·5 and 1 km. On the average, the wind speeds are about 25—40 km./hr. and do not show much change with height above 1 km. From Karachi to Gaya also, the predominant wind directions are the same but south-westerlies are also met with in Rajputana. From Patna to Calcutta, although the winds above 2 km. generally blow from some north-westerly direction, in the lower levels the directions are often south-easterly in Bihar and mostly south or south-west in Bengal. In the Brahmaputra Valley, the main directions are from the east and from the west, the former being more common from the surface up to 1·5 km. and the latter at 2 and 3 km.

Along the Burma Coast up to Rangoon the winds are generally southerly to south-westerly in the lower levels over most parts of the route, but weak north-westerlies are also met with in the neighbourhood of Akyab. With increase of height, the winds gradually veer to west or west-north-west.

South of Rangoon, the winds are generally weak and of indefinite direction with a tendency to become easterly in Tenasserim at 2 and 3 km.

The winds in Gujarat and the central parts of the country are also mainly from the west and north-west, but are more unsteady in the latter region.

In the Peninsula, the wind direction undergoes a marked change with height. In the lowest kilometer, they are mostly from a northerly direction along the west coast and from a southerly to south-westerly direction along the east coast ; the latter extend further into the interior of the Peninsula than the northerlies of the west coast. At 2 km. in the south of the Peninsula the winds are mainly from the east and north-east, while in the Deccan the direction is indefinite. At 3 km., the direction is generally from north to north-east over most of the region, the only marked exception being the west Deccan where southerly winds are frequent at this level.

The wind speeds show a marked increase with height in the United Provinces and Bihar and in the south of the Peninsula ; in the former region the mean speeds increase from about 25 km./hr. at 1 km. to 40 km./hr. at 3 km., and in the latter from about 15 km./hr. at 1 km. to 30 km./hr. at 3 km.

The monsoon season (June—September).—July (*Fig. 11*) can be taken as a representative month of this season. By the beginning of this month, in normal years, the monsoon is established throughout the country and the wind system is mainly dominated by the low pressure area over Persia, Baluchistan and Sind and the low pressure trough along the Gangetic valley. Depressions move more or less regularly in a westerly to north-westerly direction from the head of the Bay of Bengal.

Described in general terms the winds at the usual flying heights are northerly to north-westerly in the Persian Gulf, north-westerly to westerly along the Mekran Coast and westerly over the whole of the Peninsula, the central parts of the country and Orissa. In SE. Rajputana, the direction is mainly west to south-west but on approaching Jodhpur, north-easterly winds are also frequent especially above 1 km. Near Agra, the winds are most frequently north-west but easterly winds are also common in connection with depressions. In the Punjab, the winds are generally from the north-west with occasional changes to south-east in the south and east of the Province.

Going down the Gangetic Valley the easterlies become more and more common, and near Patna only about 25 per cent. of the winds are westerly. In south-west Bengal south-westerly winds are most common, while in the east and north south-east and east are the main directions. Down the Burma Coast, southerlies to south-easterlies are most frequent near Chittagong, south-westerlies near Akyab and west to south-westerlies near Rangoon and further south.

There is great steadiness in wind direction over most parts of the area. The largest variations occur in the neighbourhood of the low-pressure trough in the Gangetic Valley and in the SE. Punjab.

The mean wind speeds irrespective of direction are smallest in the Punjab, upper Sind and Baluchistan where they are of the order of 10—30 km./hr. The speeds are largest in the Peninsula, the mean values ranging from 30—60 km./hr.

The transition monsoon season (October—November).—The monsoon definitely withdraws from most parts of north India and the central parts of the country in October (*Fig. 12*). An anti-cyclone is established over north-west India at about the same time and a regime of north-westerly winds prevails close to the Himalayas. In the south of the Peninsula and of the Bay of Bengal and in Lower Burma the westerly to south-westerly winds of June to September weaken and become variable in direction in October; in November north-easterly rain-bearing winds become active.

We shall now briefly consider the upper winds in November.

In the Persian Gulf, the winds at all levels up to 3 km. are mainly north-westerly, but on its eastern side and along the Mekran Coast, north-easterlies and easterlies are more common up to 2 km. The winds are also generally weak in the first two kilometres, but the north-westerlies at 3 km. are moderately strong with 25—40 km./hr. From Karachi to Calcutta also the winds are mainly north-westerly, except that in east Rajputana easterly to north-easterly winds are also fairly frequent up to 1·5 km. In Assam and north Bengal the easterly valley winds characteristic of the winter and early summer blow down the Brahmaputra Valley. The mean speeds irrespective of direction

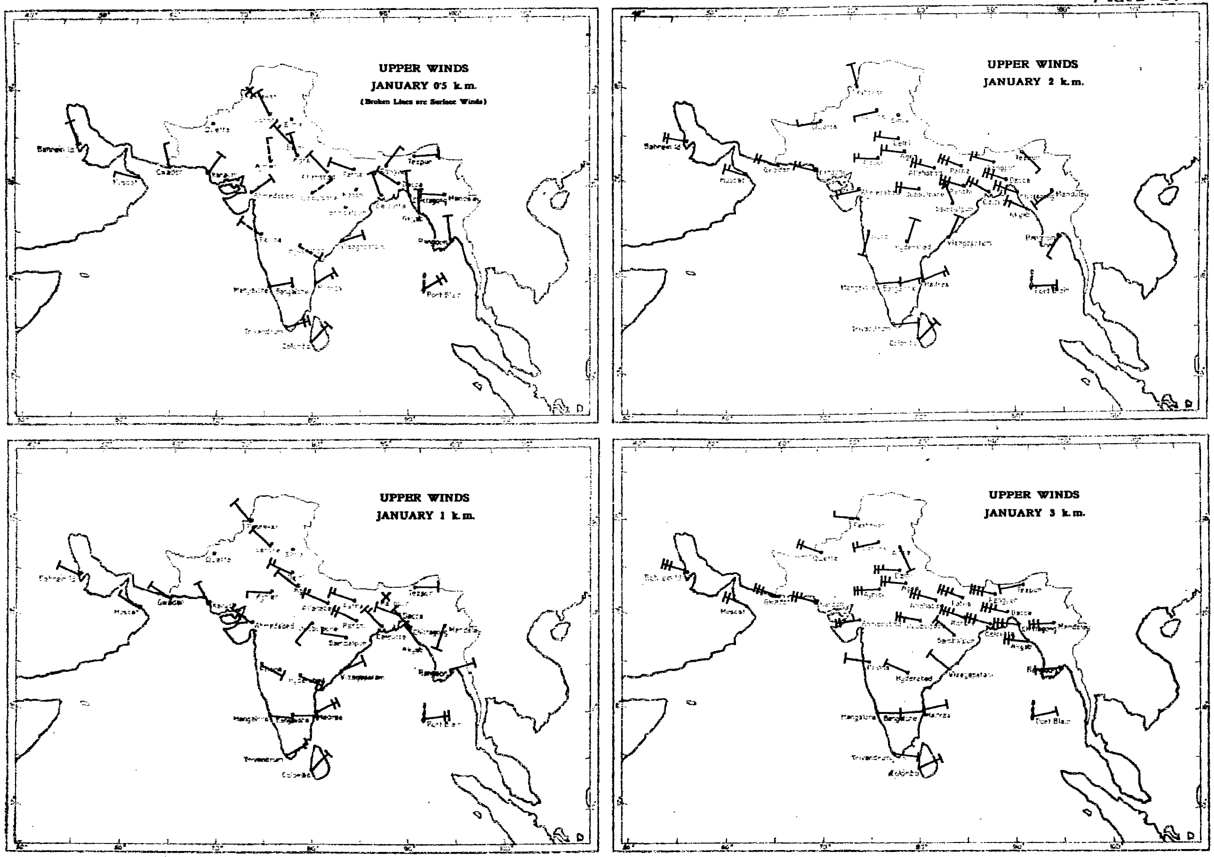

FIG. 9. UPPER WIND CHARTS. JANUARY.

G.F.Z.O. POONA, 1935.

Plate 7.

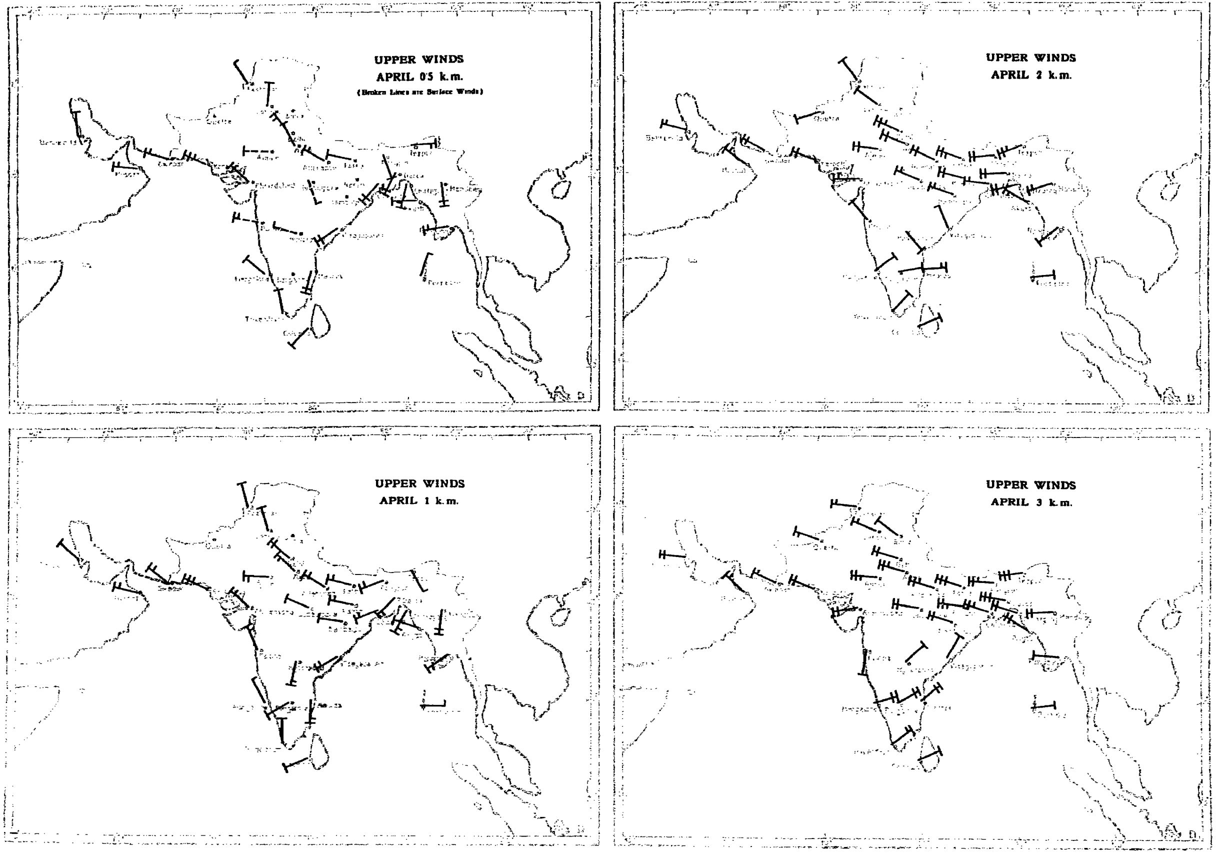

FIG. 10. UPPER WIND CHARTS. APRIL.

Plate 8.

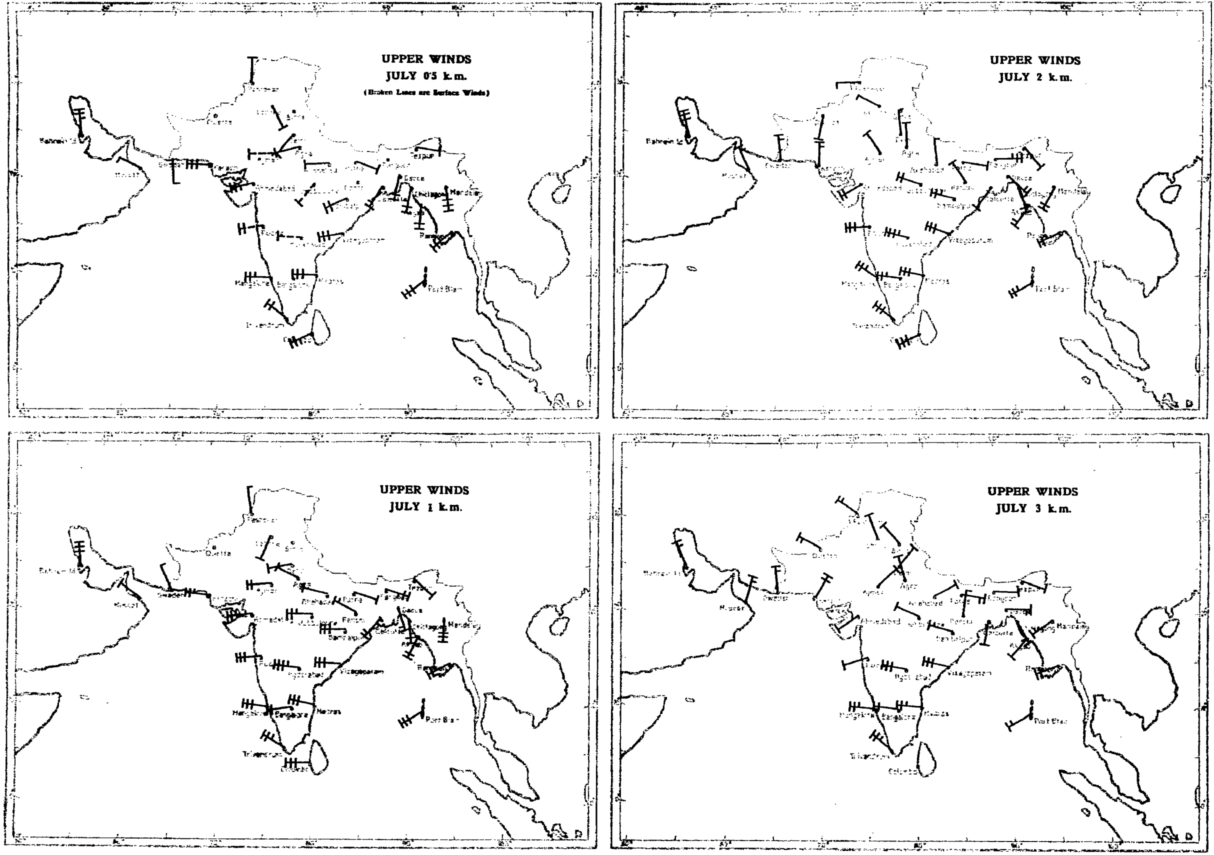

FIG. 11. UPPER WIND CHARTS. JULY.

G.P.,P.O. POONA, 1935.

Plate 9.

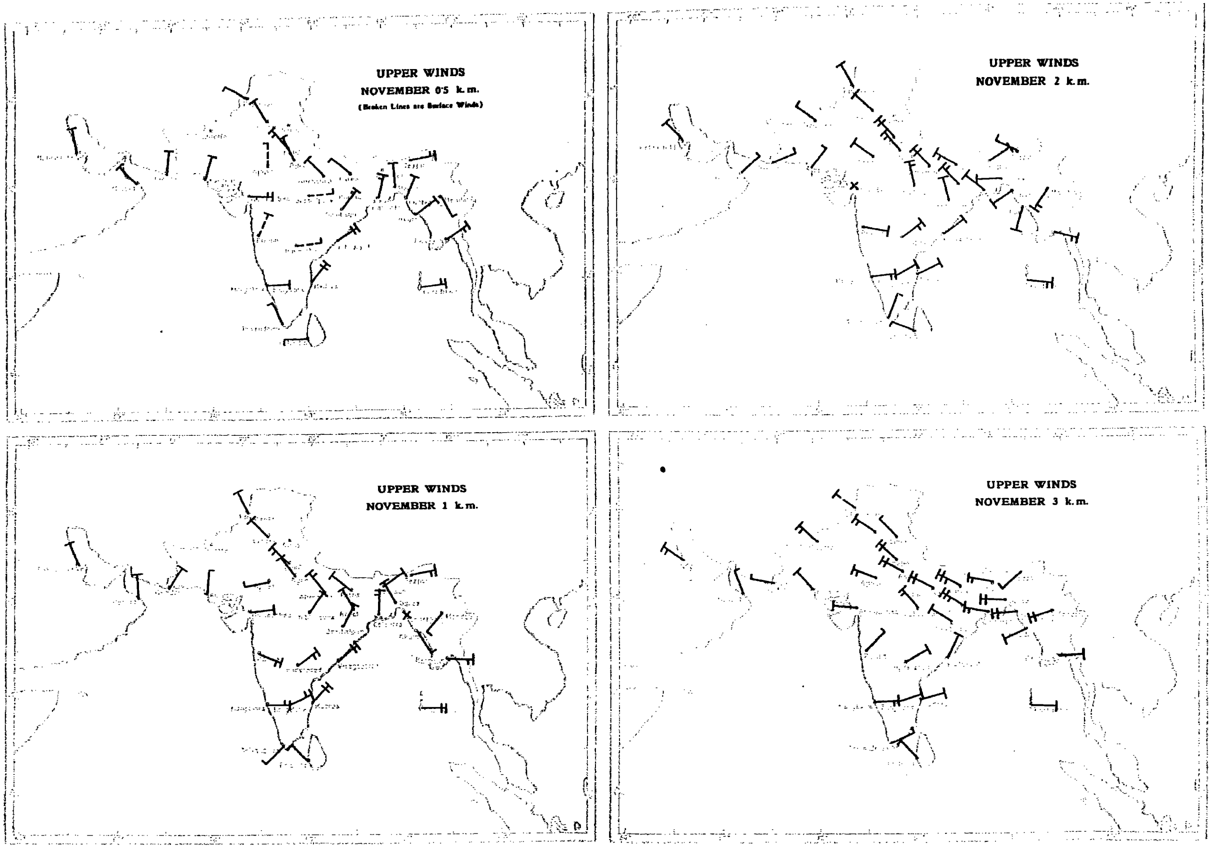

FIG. 12. UPPER WIND CHARTS. NOVEMBER.

Plate 10.

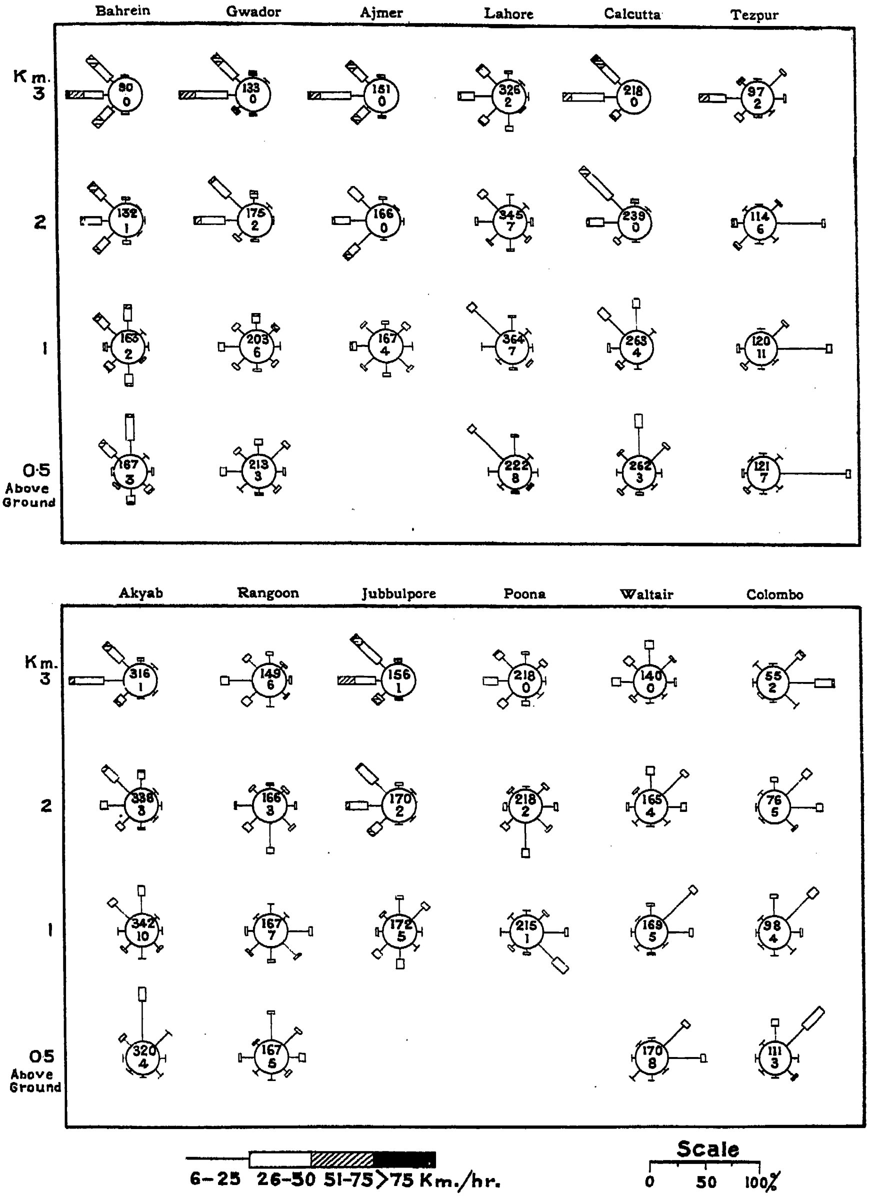

FIG. 13. WIND ROSES FOR JANUARY.

G.P.Z.D.Poona, 1935.

Plate II.

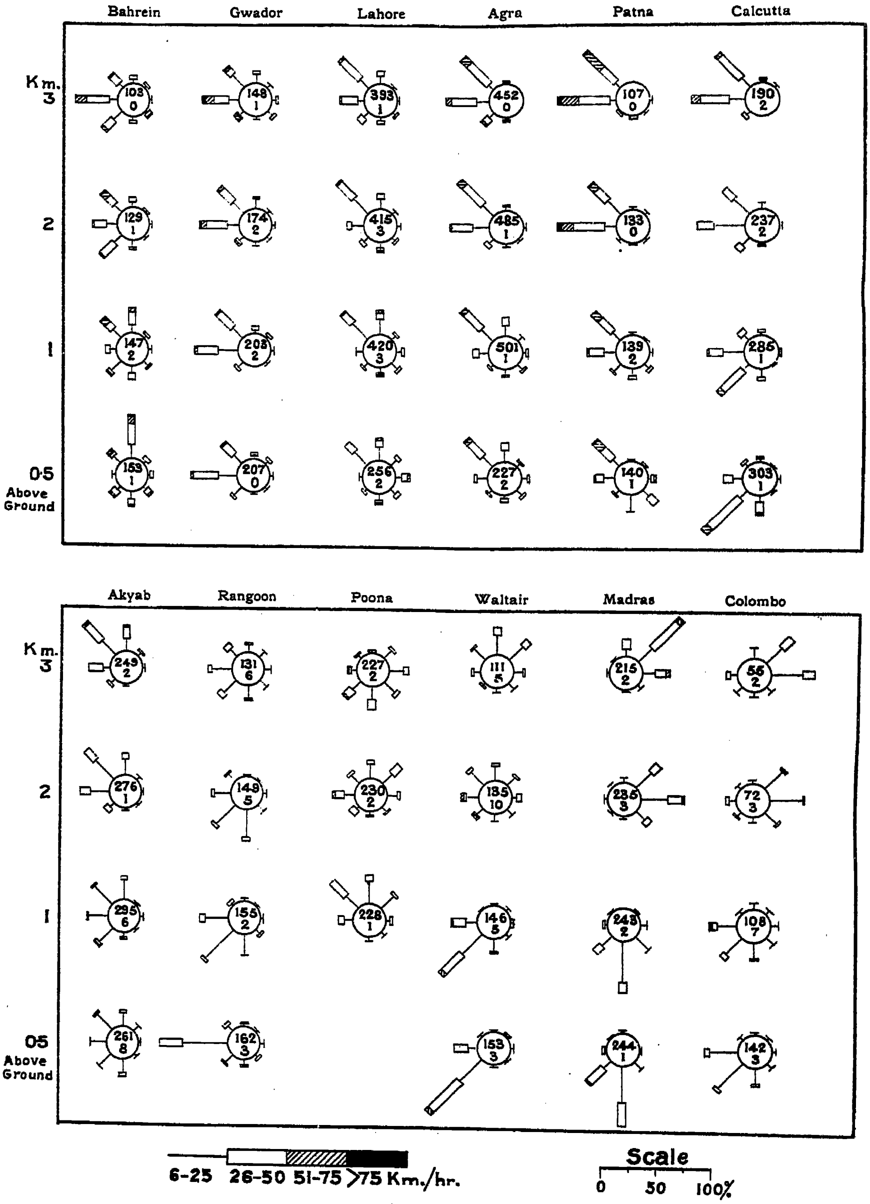

FIG. 14. WIND ROSES FOR APRIL.

G.P.Z.O. Poona, 1935.

Plate 12.

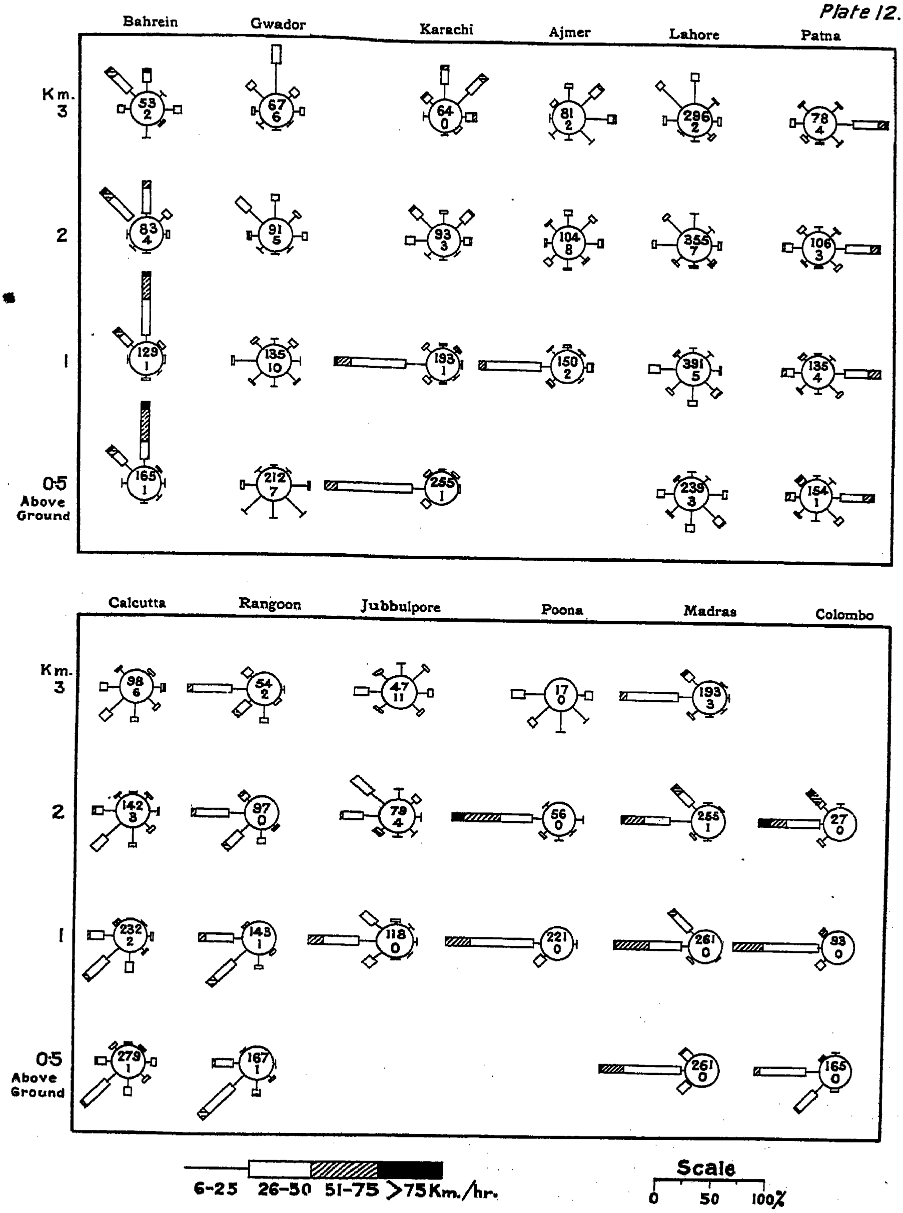

FIG. 15. WIND ROSES FOR JULY.

G.P.Z.O. Poona, 1935.

Plate 13.

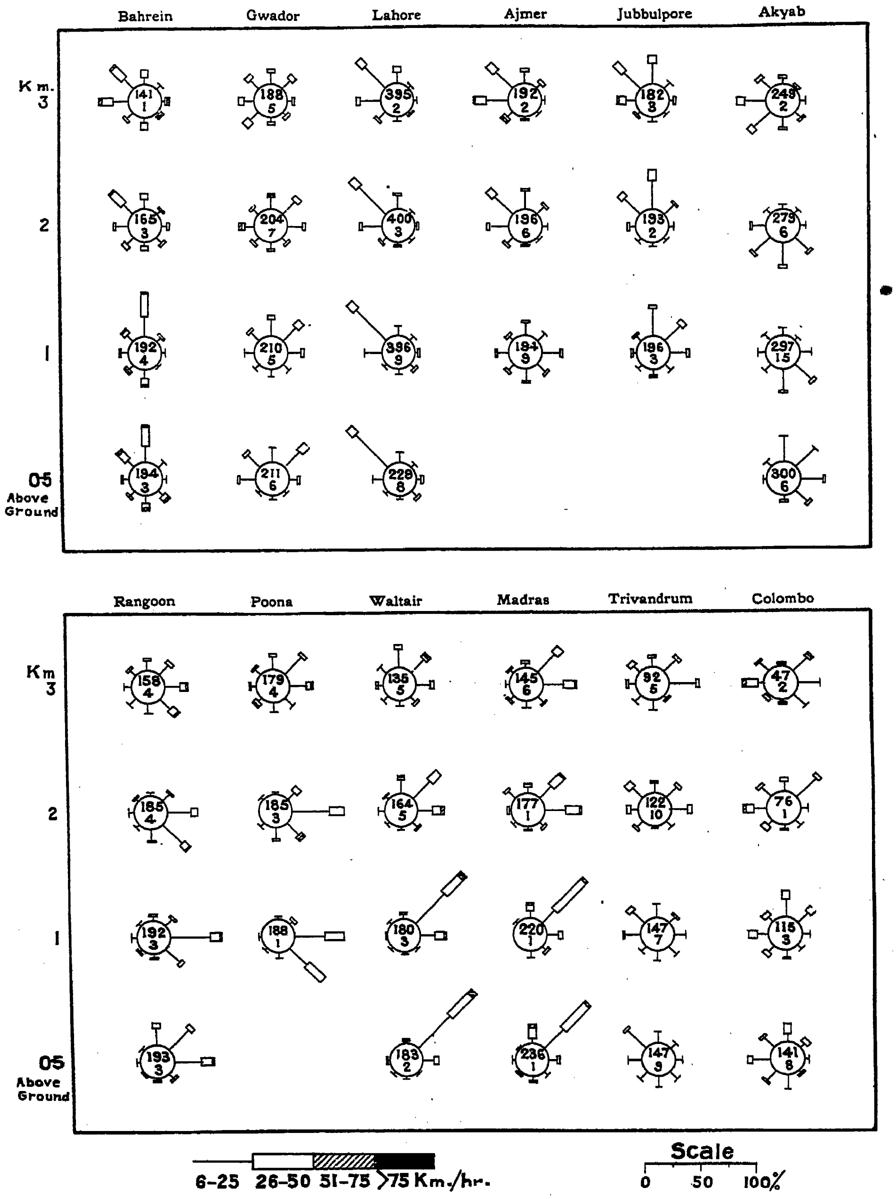

FIG. 16. WIND ROSES FOR NOVEMBER.

G.P.Z.O. Poona, 1935.

in the region Karachi to Calcutta are 15—25 km./hr. in the first 2 km. and 25—40 km./hr. at 3 km. Going down the Burma Coast, the principal wind direction in the first 2 km. is from the south or south-west up to Akyab. South of Akyab, it changes over to south-east and becomes easterly near Rangoon. In Tenasserim, the winds are generally from the east or north-east. At 3 km. north-westerly winds are common from Calcutta to Akyab. Near Rangoon, the direction is variable with a preference for the easterly, while further south it is definitely easterly. The mean wind speeds are 10—25 km./hr. on the Arakan Coast but rise to 15—30 km./hr. south of Rangoon.

In the north of the Peninsula, the principal wind direction is from north-west and north and in the south of the Peninsula from north-east to east. Westerly winds sometimes occur at Trivandrum and in Ceylon. The mean wind speeds are 10—25 km./hr. in the north of the Peninsula and 15—30 km./hr. in the south.

Note on upper air-tables and diagrams.

The tables are based on observations up to the end of 1931; the minimum number of years' data for any station is *3*.

D is the resultant direction.

v is the resultant velocity in *kilometres per hour.*

V is the mean speed (irrespective of direction) in *kilometres per hour.*

D′, *D″* are the two most representative directions* from which the wind comes. These are based on frequency tables.

Var. means variable.

In the charts, ***Figs. 9—12,*** the number of feathers in each arrow is the Beaufort number of wind speed.

**N.B.*—When two adjacent directions, say N and NW, are both more frequent than an altogether different direction, say S, and the last is also fairly frequent, the two representative directions are given as NNW and S and not as N and NW. When two directions are almost equally frequent, the direction from which stronger winds blow has been written first. A few cases have been indicated like NW-S. This means that all directions from NW to S are common, with a preponderance of directions near the first-mentioned one. The change from the first direction to the second takes place through the shorter angle: thus NW-S should be taken to represent NW, W, SW and S and not NW, N, NE, E, SE and S.

TABLE 4.

MEAN UPPER WIND DIRECTIONS AND VELOCITIES.

JANUARY.

	0·5 km.					1 km.					2 km.					3 km.				
	D	v	V	D′	D″	D	v	V	D′	D″	D	v	V	D′	D″	D	v	V	D′	D″
Bahrein	NNW	10·5	29·1	NNW	SSE	WNW	9·3	26·7	NNW	S	W	23·3	31·4	SW to NW		W	36·7	41·7	SW to NW	
Gwador	NNW	3·5	18·0	W to NE		WNW	6·1	20·6	NW	Var.	WNW	23·3	28·8	WNW		WNW	37·0	41·7	WNW	
Karachi	NNE	11·6	23·8	NE to NW		NNW	7·9	19·8	W to NE		W	15·8	24·1	WSW to NNE		W	32·8	38·9	WNW	
Ajmer						W	4·3	18·0	W	ENE	W	19·5	26·7	SW to NW		W	35·6	42·2	SW to NW	
Delhi	NW	15·1	24·0	NW		WNW	16·3	23·8	NW	W	W	18·3	24·1	WNW	SW	W	30·9	34·9	WNW	SW
Agra	NNW	9·0	20·6	NW	ESE	NW	8·7	19·8	NW	SE	W	19·2	25·9	WNW	SW	W	32·3	37·0	SW	NW
Allahabad	NW	5·8	15·4	NW		WNW	13·7	19·2	WNW		WNW	31·4	35·2	WNW		WNW	38·5	41·4	WNW	
Jubbulpore						SW	2·1	18·3	NNE	S	W	21·9	28·5	SW to NW		W	32·3	38·1	WNW	
Patna	WNW	9·0	16·6	WNW	ESE	WNW	16·3	20·6	WNW		WNW	39·9	41·7	WNW		WNW	55·8	57·3	WNW	
Calcutta	NNW	10·0	18·0	N	Var.	NW	13·7	18·7	NNW		WNW	28·0	31·7	WNW		WNW	37·8	39·9	NW to WSW	
Dacca	NW	7·9	12·6	NE	W	WNW	11·1	14·3	NW	SSW	WNW	34·6	36·7	WNW		WNW	46·8	49·7	WNW	
Tezpur	E	11·1	15·4	E		E	6·4	14·3	E		SSE	2·1	16·3	E	WSW	W	11·9	24·1	W	ENE
Mandalay	W	7·2	11·9	SSE	N	SSW	6·4	13·0	SSW	N	WSW	18·3	22·4	WSW		W	35·6	40·4	W	
Akyab	N	11·6	16·6	N		NNW	8·7	16·9	NNW		WNW	15·8	24·1	SW to N		W	28·5	32·3	WNW	
Rangoon	N	6·1	15·1	NNE	W	E	8·2	14·8	ESE	Var.	SW	8·7	17·2	SE to W		W	12·6	20·9	W	Var.
Port Blair	ENE	21·6	24·8	ENE		E	21·9	24·8	E		E	16·9	21·9	ESE		E	12·2	16·6	E	
Ahmedabad	NE	11·1	22·7	NW to E		NW	4·3	16·3	Var.		WSW	18·0	25·9	SW to NW		W	27·0	35·2	SW to NW	
Poona						ESE	6·1	16·6	ESE	W	SSW	10·0	18·0	SSE	Var.	W	12·6	24·1	SW to N	
Madras	ENE	18·0	21·9	ENE		ENE	20·1	23·0	ENE		ENE	16·3	21·9	ENE		ENE	9·3	17·2	SE to N	
Waltair	ENE	7·2	16·3	ENE		ENE	10·5	19·2	NE		NNE	7·6	18·7	NE	Var.	NW	10·5	20·6	W	NE
Trivandrum	ENE	8·7	27·0	SE	N	ENE	4·7	10·8	NE	SW	E	6·4	16·3	ENE	S	E	10·1	20·1	E	
Colombo	NE			NE		NE			NE		NE			ENE		ENE			E	
Quetta											WSW	5·0	13·0	NW	S	WNW	22·4	28·8	SW to NW	
Peshawar	WNW	0·6	7·9	W to N		NW	7·9	10·8	W to N		NNW	8·2	14·8	NNW	NNE	W	3·2	16·3	Var.	
Lahore	NNW	9·0	16·9	NNW		NW	6·9	15·8	NW		WSW	5·0	16·6	SW to NW		WSW	13·7	23·0	S to NW	

TABLE 4.—*contd.*

MEAN UPPER WIND DIRECTIONS AND VELOCITIES—*contd.*

APRIL.

	0.5 km.					1 km.					2 km.					3 km.				
	D	v	V	D′	D″	D	v	V	D′	D″	D	v	V	D′	D″	D	v	V	D′	D″
Bahrein . .	NNW	10·8	29·9	N	S	WNW	10·1	27·7	SSW	N	W	17·2	29·9	SW	NW	W	21·2	34·3	SW	N
Gwador . .	W	19·8	24·8	WNW		WNW	18·3	26·7	WNW		WNW	21·6	26·2	WNW		WNW	16·6	26·7	SW to N	
Karachi . .	WNW	29·9	34·3	WNW		WNW	28·0	33·8	WNW		WNW	24·8	29·9	WNW		WNW	20·1	31·4	NW	Var.
Ajmer . .						W	14·8	24·9	NW		W	25·9	32·0	WNW		W	27·4	33·5	SW	NW
Delhi . .	NW	17·7	27·7	NW		NW	20·6	27·4	NW		WNW	28·0	32·0	WNW		WNW	26·7	33·2	NW	
Agra . .	NNW	11·6	25·9	NW	SE	NW	14·0	24·1	W to N		WNW	24·1	28·5	WNW		WNW	30·9	37·0	WNW	
Allahabad . .	WNW	3·5	22·4	NW		WNW	17·7	21·2	NW		WNW	24·1	27·0	WNW		WNW	30·9	33·5	WNW	
Jubbulpore .						WNW	10·5	23·8	W	NE	WNW	16·6	21·9	WNW		WNW	23·0	25·9	WNW	
Patna . .	WNW	9·7	27·0	WNW	SE	WNW	19·2	27·7	WNW	S	WNW	34·3	35·2	WNW		WNW	41·4	43·9	WNW	
Calcutta . .	SW	24·8	27·7	SW	NW	WSW	19·2	26·7	SW	NW	WNW	19·2	23·3	WNW		WNW	29·9	33·5	WNW	
Dacca . .	SSW	21·9	28·5	SSW	WNW	SW	20·9	25·6	SW		W	23·8	28·8	WNW	SSW	WNW	34·6	37·5	WNW	
Tezpur . .	E	18·3	26·2	E		SSE	5·0	19·2	E	W	WSW	28·8	31·7	W	SE	W	34·6	36·0	W	
Mandalay .	S	23·8	28·0	S		S	20·9	26·2	S		WSW	17·2	23·3	NW to SW		W	26·2	29·9	WNW	
Akyab . .	W	6·4	14·3	S to W to N		WNW	9·7	15·4	SW to N		NW	15·8	22·4	W to N		NW	21·2	27·0	NW	
Rangoon . .	W	15·4	12·6	W		WSW	14·0	18·3	WSW		SW	9·0	16·3	S to NW		W	7·9	17·7	SW to NW	
Port Blair .	NNE	2·9	12·2	ENE	WSW	E	2·9	12·6	E	SW	E	9·0	16·9	NE to SE		E	10·1	18·3	E	Var.
Ahmedabad .	NW	20·1	30·3	NW		NW	14·8	23·3	W to NNE		W	15·8	20·9	SW to NW		WSW	22·4	28·0	WSW	
Poona . .						NNW	15·1	21·9	NNW		NW	8·2	23·8	WNW	NE	S	10·5	22·4	SSW	NE
Madras . .	SSW	21·9	25·3	S		S	14·0	18·7	S		E	17·2	21·6	NE to SE		NE	24·1	28·8	NE	
Waltair . .	WSW	23·0	25·3	SW		WSW	17·7	22·4	SW		NNW	2·6	14·8	WSW to NE		NNE	9·7	17·2	NW to NE	
Trivandrum .	N	8·7	12·2	N		N	8·7	14·3	NNE	SE	NE	9·3	19·8	NE		NE	15·4	26·7	NE	
Colombo . .	SW			SW		WSW			WSW		ENE			NE to SE		ENE			ENE	
Quetta . .											WSW	6·1	15·1	S	NW	WNW	18·7	26·2	NW	WSW
Peshawar . .	NW	4·0	10·1	NNW		NNW	7·9	13·7	NNW		NW	9·7	16·9	NNW	Var.	W	13·4	23 3	SW to NW	
Lahore . .	N	11·6	24·5	NW	ESE	NNW	8·2	21·2	NW	SE	WNW	12·6	21·9	NW	Var.	WNW	19·2	29·1	WNW	

TABLE 4.—*contd.*

MEAN UPPER WIND DIRECTIONS AND VELOCITIES—*contd.*

JULY.

	0·5 km.					1 km.					2 km.					3 km.				
	D	v	V	D′	D″	D	v	V	D′	D″	D	v	V	D′	D″	D	v	V	D′	D″
Bahrein	NNW	34·3	45·7	N		NNW	41·7	44·3	N	NW	NNW	34·9	40·4	NNW		NW	18·0	28·0	NNW	
Gwador	S	5·5	13·0	E to S to W		NNW	3·2	15·4	W	Var.	NNW	12·6	20·9	NW to NE		NNW	15·4	20·9	NW to ENE	
Karachi	W	35·6	38·1	W		W	27·7	32·3	W		N	13·4	24·1	WNW	NE	NNE	24·1	31·7	NW to ENE	
Ajmer						W	22·7	31·4	W		NW	5·8	20·9	NE	Var.	NE	9·0	23·3	NE	
Delhi	SW	4·7	24·8	WNW	SE	WSW	6·1	27·7	W	ESE	N	4·3	24·1	NW	ESE	NE	7·2	23·3	NW	ENE
Agra	WSW	6·9	25·9	W	E	WNW	7·6	26·2	WNW		N	8·2	23·3	NW		NNW	9·0	24·1	NNW	E
Allahabad	W	7·6	25·6	W	E	WNW	11·1	27·0	W	SE	N	3·5	26·2	NW	E	NE	6·1	21·9	E	WNW
Jubbulpore						W	32·0	35·6	W		WNW	21·2	27·4	WNW		WNW	9·7	19·2	W	NE
Patna	ESE	10·5	25·9	ESE	W	ESE	9·7	25·9	E	W	ESE	10·1	25·6	E	W	ESE	15·1	28·5	E	WNW
Calcutta	SSW	17·2	29·5	SW		SW	16·3	28·0	SW		SW	11·6	22·7	SW		SSW	7·6	20·9	SW	
Dacca	SSW	21·9	28·8	SSW		SSE	19·2	28·0	SE	SW	SE	18·7	27·0	E to SW		ESE	16·9	25·3	E	W
Tezpur	ESE	7·2	15·8	E	W	SE	6·4	17·7	E	S	SE	6·4	20·1	E	SW	ESE	11·1	20·9	E	
Mandalay	S	40·4	40·7	S		S	45·1	45·4	S		SSW	26·7	29·1	W		SW	14·0	24·8	SE to W to NW	
Akyab	S	21·6	26·7	S		SSW	22·4	27·0	SW		SW	17·2	24·5	SW	S	SW	11·6	22·4	SE to W	
Rangoon	SW	31·4	34·3	WSW		WSW	33·5	36·4	WSW		WSW	31·7	34·9	WSW		WSW	25·9	30·6	WSW	
Port Blair	SW	40·4	43·6	SW		WSW	43·6	45·7	SW		WSW	27·7	31·7	WSW		WSW	16·9	25·3	WSW	SSE
Ahmedabad	WSW	28·8	33·5	WSW		WSW	32·8	34·9	W		SW	20·6	28·5	SE to W		SW	6·4	23·3	Var.	
Poona						W	38·1	42·2	W		W	41·7	44·6	W		WSW	12·6	21·9	WSW	
Madras	W	38·5	40·7	W		WNW	41·4	43·6	WNW		WNW	36·0	38·5	WNW		W	31·4	33·8	W	
Waltair	W	36·4	37·5	W		W	38·5	40·7	W		WNW	41·4	45·7	WNW		WNW	37·0	39·6	WNW	
Trivandrum	NW	21·6	23·8	NW		WNW	30·9	34·3	WNW		NW	42·5	48·0	W		NW	32·3	41·4	W	
Colombo	WSW			WSW		W			W		WSW			W						
Quetta											S	7·2	11·9	S		WNW	15·4	20·9	NW	
Peshawar	N	8·2	12 2	NNW		N	2.9	10.1	NW		W	4·7	12·6	WNW		WNW	15·1	18·7	NW	
Lahore	SSE	0·1	21·6	SSE		SSW	6.9	18.7	W to SE		WNW	4·7	16·6	WNW		NNW	10·5	19·2	NNW	

TABLE 4—*contd.*

MEAN UPPER WIND DIRECTIONS AND VELOCITIES—*contd.*

NOVEMBER.

	0·5 km.					1 km.					2 km.					3 km.				
	D	v	V	D′	D″	D	v	V	D′	D″	D	v	V	D′	D″	D	v	V	D′	D″
Bahrein . .	NNW	9·3	23·8	NNW	SE	NNW	9·0	22·4	N		NW	7·6	21·6	NW	SE	WNW	13·0	24·8	NW	W
Gwador . .	N	7·6	15·8	NE	WNW	NNE	6·9	15·8	NW to	E	ENE	5·0	16·6	NE	W	W	4·0	18·7	SW to	NE
Karachi	N	8·2	20·9	WNW	NE	N	2·9	16·9	W	NE	NNE	5·0	17·7	NE	Var.	NW	6·1	21·2	NW	Var.
Ajmer . .						W	2·1	13·0	WNW	E	NW	9·3	16·3	W to	NE	WNW	15·1	21·2	WNW	
Delhi . .	NW	13·0	16·6	NW	NE	NW	18·0	20·9	NW	NE	NW	23·3	27·7	WNW	SE	NW	21·9	27·4	NW	
Agra . .	NNW	7·6	16·9	NW	N	NW	11·1	17·2	NW	N	NW	18·7	23·3	NW	W	WNW	20·6	25·9	WNW	
Allahabad .	NW	7·9	13·7	NW	E	NW	13·0	16·9	NW	NE	NW	22·7	26·2	NW	N	WNW	25 3	31·4	NW	SW
Jubbulpore .						NE	7·6	15·8	NE	S	NNW	15·4	20·9	NW to	NE	NW	16·6	22·4	W to	N
Patna . .	NW	4·7	11·6	WNW		NW	8·7	14·3	WNW	NE	WNW	16·6	24·5	WNW		WNW	34·3	36·4	WNW	
Calcutta . .	NNE	14·0	18·3	N	NE	N	13·0	16·9	N	NE	NW	11·6	19.2	NW		WNW	19·8	25·3	SW to	NW
Dacca . .	N	5·8	10·5	NE		NNW	6·9	11·9	N	NW	W	12·6	18·7	NW		W	26·2	29·1	W	NW
Tezpur . .	E	14·3	15·8	E		E	14·0	16·6	E		WNW	5·0	16·3	E	SW	SW	2·9	19·5	SW	NE
Mandalay .	SSE	3·2	9·3	SSE	N	SW	1·8	10·8	N		SW	13·0	16·9	SW	S	WSW	20·1	28·5	W	SW
Akyab . .	NE	5·8	12·6	N to	SE	SSE	4·3	11·6	SE	S	SSW	8·2	16·3	SE	W	WSW	11·6	19·5	S to	NW
Rangoon . .	ENE	14·8	20·6	N to	E	E	13·7	18·0	E	NE	ESE	13·7	19·2	ESE		E	7·6	19·2	E	Var.
Port Blair .	E	18·0	23·8	E	NE	E	20·1	26·7	E	NE	E	15·1	23·8	E	SE	E	11·6	20·1	E	
Ahmedabad .	E	17·7	20·9	E		E	10·8	14·0	NNE to	SE	SE	1·1	12·6	NE	Var.	W	7·9	16·3	WSW	NE
Poona . .						ESE	14·3	19·8	SE	E	E	10·1	17·7	E	SE	NE	4·3	17·2	NE	Var
Madras .	NE	22·4	28·5	N to	E	NE	21·6	28·0	NE		ENE	10·5	22·4	ENE		ENE	10·5	18·3	ENE	
Waltair . .	NE	21·2	24·1	NE		NE	20·1	23·8	NE		NE	11·6	19·2	N to	E	NNE	6·1	16·6	N to	E
Trivandrum .	SW	1·8	9·7	NW	Var.	SW	2·1	12·2	NW	Var.	NNE	1·8	15·4	NW	E	ENE	4·3	17·7	ENE	Var.
Colombo .	W			Var.		NW			N	W	WNW			NE	W	NW			ENE	WNW
Quetta . .											WNW	4·0	10·1	NW		NW	16·6	22·4	NW	
Peshawar . .	W W	2·6	6·4	N	NW	NNW	6·9	9·0	N	NW	NW	10·5	15·1	NW	N	NW	11·9	18·3	NW	
Lahore . .	N W	7·6	16·3	NW		NW	9·3	14·8	NW		NW	12·2	17·7	NW		WNW	14·3	21·2	NW	

CHAPTER 3.

LOCAL WEATHER VARIATIONS AND DISTURBANCES.

Decrease of temperature and pressure with altitude.—It is well known that in the lower atmosphere there is a decrease of temperature with height. It is usual to speak of the rate of decrease of temperature with height as the "lapse-rate of temperature". It amounts on the average to 6° C. per kilometre (3·3° F. per 1,000 ft.). This is true for the free atmosphere, far away from mountains. On high lands, however, air temperatures differ materially from those of the free air at the same elevation and latitude. According to Hann, the average temperature on high lands decreases approximately at the rate of 1° C. per each 180 metres, 200 metres, and 250 metres increase of elevation, on mountains, hills and plateaus respectively.

The cause of decrease of temperature with altitude is complex, but primarily it is due to dynamic heating and cooling. By this is meant that, if air is compressed, work is done on it and its temperature is raised, and if expanded, it does work and is cooled. For example when air is forced into a tyre by means of a pump, its barrel becomes too hot to touch ; conversely, if air is allowed to escape, the orifice becomes cooled. Air pressure and therefore air density diminishes with altitude ; hence, ascending air expands and descending air is compressed. So long as air is unsaturated and if it neither gains heat from the surrounding air nor gives up heat to it, the expansion when rising and the contraction when falling are such that a change of temperature of approximately 1° C. per 103 metres change in altitude is produced. This lapse-rate of 1° C. per 103 metres (or 5·3° F. per 1,000 feet), is known as the adiabatic lapse-rate. An atmosphere with this lapse-rate has the property that, if any portion of it is transferred without gain or loss of heat from one level to another, it will have the same temperature and density as the adjacent air in the new level, and therefore, if not acted on by other forces, will remain in equilibrium in its new position. If the lapse-rate is less than the adiabatic lapse-rate, then an isolated mass of air on being raised, without loss or gain of heat, will become colder and denser than the neighbouring air at the same level, and consequently, if left to itself, it will return to its original level ; if lowered, it will become warmer and lighter than the surrounding air and therefore rise again. On the other hand, if the decrease of temperature with altitude is greater than the adiabatic rate, an isolated mass of air on being lifted (or depressed), without gain or loss of heat, will continue to rise (or fall) until arrested by the existence of some different conditions in the atmosphere. An isolated mass of air is consequently in neutral, stable, or unstable equilibrium, according as the lapse-rate of temperature, where it rests, is the same as, less than or greater than the adiabatic rate of 1° C. per 103 metres.

Table 5 gives the mean monthly lapse-rates over northern and southern India.

Table 6 gives the pressures at different heights. The decrease of pressure per kilometre is about 8 to 12 per cent.

TABLE 5.

MEAN MONTHLY LAPSE RATES IN DEGREES CENTIGRADE PER KILOMETRE.

Height range.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct	Nov.	Dec	Annual mean.
							NORTHERN INDIA.						
(Km.)													
Surface—2 .	5·7	6·3	7·9	6·9	8·8	8·3	5·5	6·2	6·8	7·9	5·6	4·9	6·7
2—4 .	5·5	5·8	6·8	8·2	8·9	8·1	4·2	4·9	5·9	6·1	5·8	5·3	6·3
4—6 .	6·4	6·4	6·8	6·7	7·1	5·9	5·3	5·3	4·9	5·7	5·8	7·1	6·1
6—8 .	5·9	6·7	6·7	6·8	6·2	5·3	5·7	5·2	5·7	6.5	6·3	7·6	6·2
8—10 .	7·1	4·5	6·0	7·1	6·7	7·2	6·3	7·3	7·5	6.9	6·3	8·1	6·7
							DECCAN.						
Surface—2 .	9·3	8·7	8·7	8·3	8·3	8·0	7·0	8·0	7·0	7.3	8·7	7·7	8·1
2—4 .	5·4	7·3	8·3	8·7	7·9	6·0	5·3	5·3	5·5	5.2	4·7	4·8	6·2
4—6 .	6·5	5·9	5·0	6·3	5·4	6·1	5·9	5·3	5·5	5·9	5·9	5·9	5 8
6—8 .	6·6	6·1	7·0	6·1	6·9	5·8	5·7	6·1	6·3	6·4	6·1	6·9	6·3
8—10 .	7·4	6·9	7·7	7·5	7·7	7·6	7·3	7·9	7·3	7·5	7·7	7·5	7·5

TABLE 6.

MEAN MONTHLY PRESSURES IN MILLIBARS (1,000 MILLIBARS =29·53 INCHES).

Height in km.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
						NORTHERN INDIA.						
1	901	898	900	897	897	892	891	894	896	901	901	903
2	799	797	801	800	801	796	794	797	799	803	800	802
3	707	705	709	708	712	708	705	707	709	711	707	710
4	622	620	627	627	631	627	625	627	628	629	624	627
6	482	479	487	486	491	490	490	492	493	490	483	487
8	365	365	370	370	376	377	378	379	379	376	368	370
10	275	275	281	281	286	288	291	290	290	286	280	279
						DECCAN.						
1	902	901	901	900	900	898	896	895	899	901	902	902
2	803	803	804	803	803	801	798	797	801	802	803	803
3	713	714	715	715	715	713	709	709	712	713	714	713
4	630	632	632	633	632	631	627	628	630	631	631	630
6	490	491	492	493	492	492	489	489	491	492	492	491
8	376	377	377	377	380	380	377	378	379	379	379	377
10	284	286	285	285	288	288	287	287	287	287	288	285

Land and sea breezes.—On clear hot days a daily movement of surface winds takes place near the sea coast, analogous to the monsoon winds, but of far less extent. The sea breeze blows from cold sea to warmer land by day and the land breeze from cold land to warmer sea at night. The sea breeze, when well developed, may reach a height of 1 km. or more and extend 50 km. to 100 km. inland, with a velocity of 25 to 30 km. per hour. The sea breeze usually attains its maximum intensity between 3 and 5 p.m. The land breeze seldom extends more than 15 km. seaward and its height and velocity are correspondingly less.

Land and sea breezes are most pronounced along the Indian coasts during the bright sunny weather of the dry monsoon, particularly when the pressure gradient is weak and ill-defined. They are least pronounced, in fact practically non-existent, during the wet monsoon when cloudy conditions prevent the land from heating up by day or cooling by night, and when the regular strong winds of the season overcome the daily reversal of conditions over land and sea.

Mountain and valley winds.—In mountainous or even ruggedly hilly country there is often, particularly at times of no general wind, a well-defined movement of air up the valleys in the day time and an even more marked flow down the valleys at night. In this class of day-and-night winds the contour of the land plays an important part. Where the valley is long and fairly steep, particularly if acting as a drainage channel for a gently sloping plateau, the down-flowing 'mountain winds' may assume the proportions of a gale and become a veritable aerial torrent. A local cold wind is called "katabatic" if it is caused by the gravitation of cold air off high ground. A local wind is "anabatic" if it is caused by the convection of heated air, as, for example, the breeze that is supposed to blow up valleys when the sun warms the ground. Mountain and valley winds are met with in various parts of India, in the slopes of the Himalayas, along the Western Ghats in the Deccan, in the North-West Frontier Province, etc.

Turbulence.—Every pilot sooner or later experiences in the course of his flights abrupt drops and more or less severe jolts which are described by such terms as "air-pockets," "air-holes", "bumps", "dunts", etc. Such bumpy conditions arise either from rapid fluctuations in the horizontal movement of air or from local ascending or descending currents and are associate" with what are in meteorological language called "gusty" or "turbulent" conditions of the atmosphere.

Turbulence (or its constituents, *viz.*, eddies) may be classified into two types (1) frictional and (2) thermal according as they owe their origin to frictional causes or to heating of the earth's surface. Obstacles on the earth's surface interfere with the free flow of air and cause changes in its horizontal movement both as regards direction as well as speed. Even in level country, appreciable gustiness due to friction extends up to 150—200 metres. In rugged country and in the neighbourhood of hills and mountains, the changes in horizontal movement are also accompanied by appreciable vertical currents. On the average, in clear weather, the gusts and swirls produced by topographic irregularities extend to about 1½ times the height of the obstructions, but in disturbed weather, especially when there is an inflow of fresh moist air, the vertical currents may extend much higher.

Vertical currents, set up thermally as the result of irregular heating of the earth's surface, constitute an important and common source of bumpiness. It is, in fact, the main cause of turbulence during day hours over the plains of

India. During clear summer afternoons rising and falling currents of convection always exist over a hot barren country. Over comparatively cooler areas such as lakes, rivers and wood, there are generally descending currents.

The rate of ascent and the height to which convection currents extend are very variable. Observations with pilot balloons show that vertical movements of 8 to 16 km./hr. are not uncommon. Unless the atmosphere is abnormally dry, such up-currents are followed by the development of cumulus or thunderstorm clouds in which the vertical movements are often much more violent, certainly 25 to 30 km./hr. when hail is formed and probably at times much higher. Descending currents of 8 to 12 km./hr. have been observed but they are, in general, much less pronounced than ascending currents.

Bumpiness due to ground heating is most pronounced in the hot season between 10 hours and 17 hours. Usually, there is practically no bumpiness at the time of sunrise but it commences within a couple of hours. The Delhi Flying Club reports that one hour after sunrise bumpiness is noticeable up to 300 metres, at the end of 2 hours up to 600 metres and at the end of 3 hours up to 1,000 metres. The maximum height to which the turbulence extends depends on the locality and on the time of the day. In the interior of north India in March to June, bumpiness generally extends in the afternoons to more than 3 km. This height may be expected to be lower in the Deccan and in Bengal but not lower than 2 km. The bumpiness is most pronounced near the top of the turbulent layer. Above the turbulent layer there is generally a marked improvement in atmospheric transparency. By sunset, the bumpiness ceases near the ground, but continues for one or two hours at higher levels with gradually decreasing intensity. In the monsoon season, bumpiness is mostly associated with cloud formation.

In regions where there is a low-lying inversion, such as exists over Karachi at 1 to 2·5 km. in many months of the year, turbulence is generally confined to the layer below the inversion. Bumps of exceptional severity may be experienced when flying in the hot weather over hilly country, especially when the level of land changes abruptly. Bumps are also experienced where dry land changes to wooded country.

Orographical peculiarities may give rise to special vertical currents in the atmosphere. For example, during winter and most of the hot season, there is an easterly current flowing down the Brahmaputra valley towards the plains of north Bengal. Above this easterly current, westerly winds prevail. At levels where one wind system changes to the other, sudden changes of wind direction and velocity and attendant bumpiness are often experienced. Over north Bengal near the mouth of the Assam valley in the months of December to March this may be expected at a height of 2 to 3 km. South of the Khasi hills, the corresponding average height is from 1 km. to 2·5 km.

Thunderstorms.—The condition essential to the formation of thunderstorms is the production of rising currents of moist air on a sufficient scale. Such large scale convection can only arise from the occurence of marked instability in the air in the locality. This instability may be caused in any of the following three ways :—

(1) Strong surface-heating of air by contact with heated ground. This mode of formation is the most common and is typical of hot sultry days in summer.

(2) Overrunning of a moist warm layer of air by a comparatively cold layer. This apparently constitutes the chief mode of genesis of all ocean thunderstorms and also occasionally of those occurring on land in connection with cyclones.

(3) Mechanical uplift of moist warm air by cold heavy air.

Thunderstorms formed by any of the processes enumerated above have the same fundamental characteristics. They are associated with the formation of towering cumulus or cumulonimbus clouds with ascending currents in front of the clouds and descending currents at the rear of the ascending currents. *Fig. 17* gives a schematic representation of a well developed thunderstorm in progress.

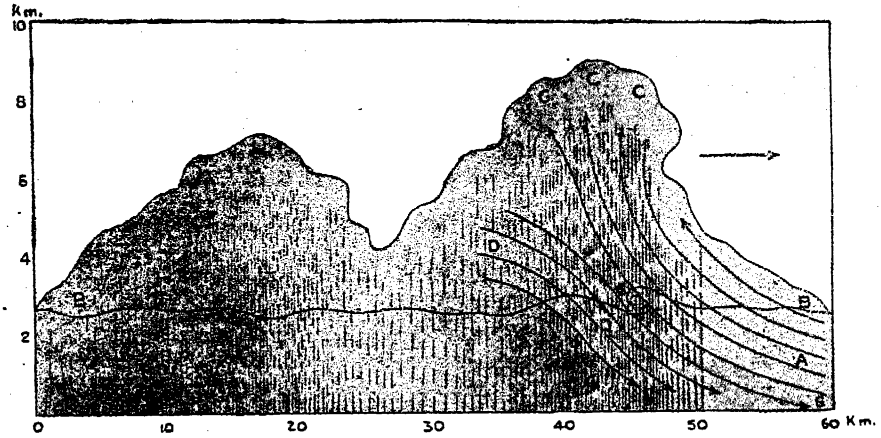

Fig 17. Air movements in the Principal Vertical Section of a Thunderstorm.

Structure and danger to flying.—Referring to the figure, the warm ascending current is in the region *A*, and the cold descending current is in the region *D*. At the interface of the ascending and descending currents is the extremely turbulent region of squall clouds *S* where invisible horizontal vertices are formed by the interaction of the two currents. The vertical movements and turbulence within a thunderstorm in the region above *A* and *D* are such that no aircraft should undertake to fly through that region. The large raindrops which fall from the most active region of a thunderstorm cannot be sustained unless the vertical wind velocity exceed 30 km./hr. and for sustenance of large hailstones a much larger vertical current is required. Ascending currents of 30 to 100 kilometres per hour may therefore be expected in the heart of a severe thunderstorm. Another important feature of a thunderstorm is the windgust at *G*. It is caused by the outrushing air of the descending currents and at times attains to velocities of 80 to 100 kilometres per hour or more, but its duration as a rule is brief. If the ground is dry, the advent of the wind gust is usually heralded by a dustcloud ; otherwise there is practically no advance warning. The squall or gust wind constitutes a real danger to landing or low flying in front of a thunderstorm. Lightning constitutes another source of danger to flying through thunderstorms if the aircraft is fitted with wireless aerial. On this question Dr. Simpson* writes as follows :—

On machines without aerials there is practically no danger to the personnel ; the position, however, is much more serious if the machine has a trailing aerial. The most important thing, therefore, to be done when it is known

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* Lightning and Aircraft, London M. O. " Professional Note " No. 66.

Plate 14.

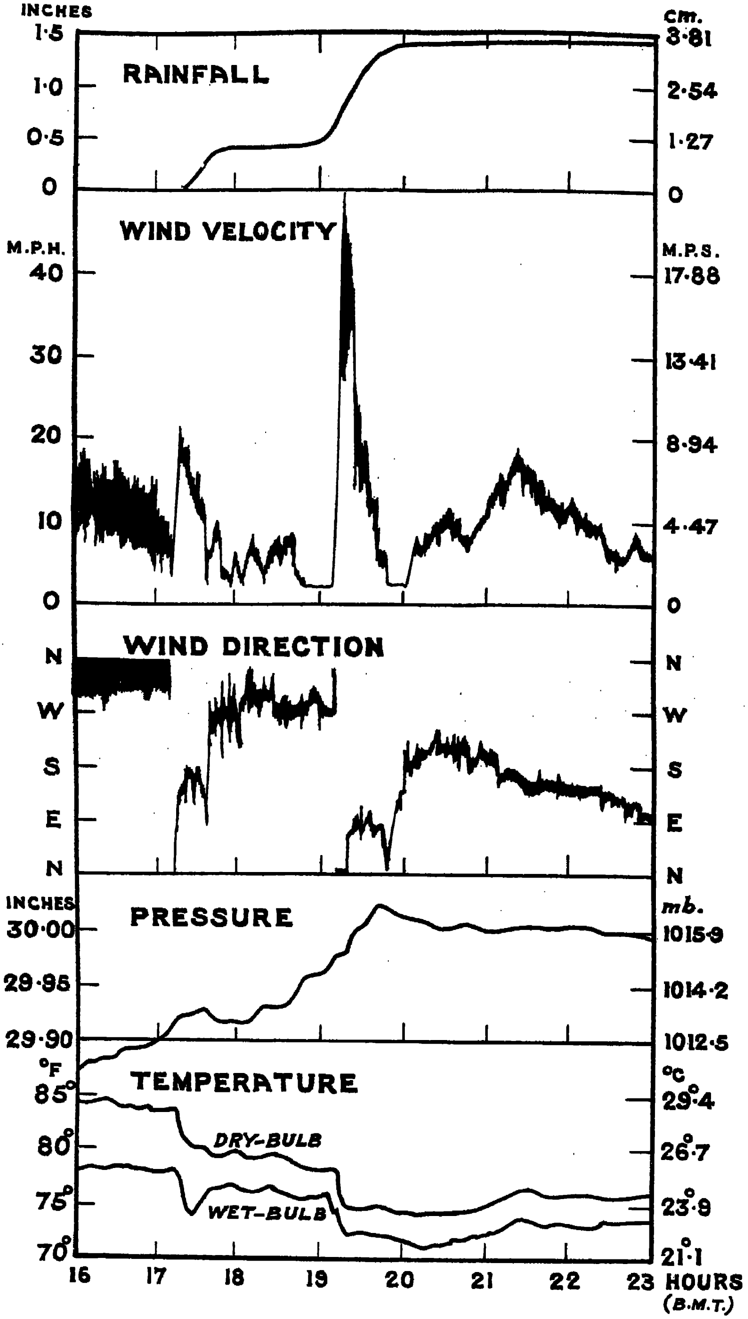


FIG. 18. CHANGES OF METEOROLOGICAL ELEMENTS IN A HEAT THUNDERSTORM.

(HEAT THUNDERSTORM AT BOMBAY, OCTOBER 6TH, 1930.)

G.P.I.O. POONA, 1936.

that the plane is in a danger area, or is about to enter a danger area, is to withdraw the aerial. Even though not actually struck; an aeroplane including metal points unconnected by conductors may collect charges able to give unpleasant though not dangerous shocks. No authentic case is on record of an aeroplane having been wrecked as the result of being struck by lightning and since January 1925, when the first report of a British aeroplane being struck by lightning was made, only ten cases have been reported.

Hail, heavy rain and poor visibility are other factors of importance to be reckoned with in flying through thunderstorms ; there is record of an aeroplane in Peshawar of which the wings and fuselage were destroyed by hail.

Dimensions, duration and velocity.—The height of the base of thunderclouds above the ground is usually between 1 and 2 km. When an overgrown cumulus first develops into a cumulonimbus cloud, it usually covers but a small area,—perhaps a few kilometres long and a kilometre or two wide. As it moves across the country it increases considerably in area, particularly along the front. After a thundershower has been in progress for a few hours it usually covers an area of the order of 150 to 200 kilometres in length and 50 to 100 kilometres in width. In individual cases a still larger area has been noted. The average life of thundershowers is about 5 to 6 hours, but owing to their progressive movement their duration at any one place is generally less than 2 hours. In a level country their average rate of movement is about 50 to 60 km./hr., but in mountainous regions they often remain practically stationary until they have " rained themselves out ". The sequence of changes in the various meteorological elements during the passage of a thunderstorm is shown in *Fig. 18*. The changes in the elements are somewhat different in different storms depending on their actual structure.

Thunderstorm frequency at selected stations is given in *Table 7*. In India there are, in general, two periods of maximum thunderstorm activity, one preceding and the other succeeding the full prevalence of the wet monsoon. The regions most subject to thunderstorms are the equatorial regions, chiefly Ceylon, Malabar and Tenasserim, where the monthly frequency is 15 to 25 in April, May, October and November.

Other regions where they are fairly frequent are Mysore, Madras and the districts round the head of the Bay of Bengal. The severest thunderstorms, including the Nor'westers of Bengal, usually occur before the monsoon and are most frequent between 3 and 7 p.m.

TABLE 7.

MEAN MONTHLY AND ANNUAL FREQUENCIES OF THUNDERSTORMS.

Stations.	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Karachi .	0·4	0·7	0·7	0·6	1·3	0·3	2·6	2·0	1·8	0·5	0	0·4	11
Agra .	0·5	0·7	1·0	1·9	2·7	4·3	6·4	6·4	3·9	1·2	0	0·6	30
Nagpur .	0·6	1·5	3·7	4·2	6·8	11·4	6·8	5·0	9·1	2·6	0·8	0·5	53
Calcutta .	0·1	0·8	3·5	6·9	6·9	7·6	5·6	5·8	9·4	3·6	0·2	0	50
Rangoon .	0	0·4	0.2	1·8	6·4	5·4	4·4	5·6	3·8	6·0	2·0	0·4	36
Diamond Island.	0·1	0	0·6	1·1	11·4	6·4	2·1	2·3	3·3	11·1	4·5	0·7	44
Victoria Point	3·5	5·6	17·4	26·3	22·1	12·3	13·4	6·8	8·8	14·4	14·7	9·0	154

TABLE 7—*contd.*

MEAN MONTHLY AND ANNUAL FREQUENCIES OF THUNDERSTORMS.

Stations.	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Bombay .	0	0	0·2	0·7	1·7	4·7	2·0	0·2	4·8	2·8	0·3	0	17
Hyderabad (Dn.).	0·4	0·3	1·6	5·3	7·6	6·4	2·6	0·9	4·8	2·7	0·6	0	33
Bangalore .	0·4	0·3	1·5	6·9	11·9	4·2	3·1	2·9	7·2	4·0	3·3	0	46
Madras .	0·3	0	1·0	2·4	6·5	6·6	7·1	8·6	10·4	9·6	4·4	0·6	57
Trivandrum	3·2	2·8	12·2	18·9	13·6	4·2	2·3	2·2	5·0	12·2	11·1	3·3	91
Lahore .	0·5	0·8	2·7	3·3	3·4	3·5	4·2	4·0	2·0	1·4	0·3	0.5	27
Simla .	1·2	2·3	5·7	7·1	7·5	13·5	10·9	7·6	5·7	3·4	1·0	1·2	67

Hailstorms.—The frequent occurrence of hail in thunderstorms affords a striking confirmation of the existence of large ascending currents within the thunder cloud. Any raindrop, which is carried aloft by strong updraft into strata of freezing temperatures, soon hardens into an ice pellet and also gathers a coating of snow outside the ice. In a lull of the ascending current, the snow-covered ice-pellet falls down to the region of liquid rain-drops and receives a further coating of water. If again carried upward to sub-freezing levels, another layer of ice and snow is formed. This process continues, adding coat after coat, until the hailstone becomes too heavy for the ascending current to sustain and it falls towards the ground. It is clear from the foregoing considerations that hail can form and grow in size only in the front portion of a heavy thunderstorm, where the vertical currents are very active. The hailstones sometimes grow to large sizes, as large as golf balls. There are records when hailstones of such large sizes covered the ground to a depth of more than a foot in a single shower. Stones of the size mentioned above can be sustained in the air only by ascending currents with speeds in the neighbourhood of 150 to 250 kilometres per hour. The area covered by a fall of hail is very much smaller than the area covered by the accompanying thundershower. It is rarely more than 8 to 10 km. in width and 50 to 70 km. in length. About 1 to 5 per cent of the hot weather thunderstorms may be expected to be associated with hail. It is worth noting that the association of hail in a thunderstorm

TABLE 8.

DAYS WITH HAIL (1901-1920).

Stations.	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov .	Dec.	Year.
Agra .	0	0·3	0·2	0·1	0	0·1	0	0	0	0	0	0·1	0·8
Nagpur .	0·1	0·3	0·3	0·3	0·2	0	0	0	0	0	0	0·1	1·3
Calcutta .	0	0·1	0·3	0·5	0·1	0	0	0	0	0	0	0	1·0
Shillong .	0	0	0·1	0·2	0·1	0	0	0	0·1	0	0	0	0·5
Rangoon .	0	0	0	0·1	0	0	0	0	0	0	0	0	0·1
Bombay .	0	0	0	0	0	0	0	0	0	0	0	0	0
Bangalore .	0	0	0·1	0·3	0·2	0	0	0	0	0	0	0	0·6
Madras .	0	0	0	0	0	0	0	0	0	0	0	0	0
Peshawar .	0·1	0·1	0·3	0·6	0·1	0·1	0·1	0	0	0·1	0	0	1·5
Lahore .	0·1	0·2	0·2	0·3	0·1	0·1	0	0	0	0·1	0	0·1	1·2
Srinagar .	0·3	0·4	0·5	0·3	0·3	0·1	0·1	0·1	0·1	0·1	0·1	0·1	2·5
Simla .	0·5	1·2	3·3	2·3	2·6	0·9	0·1	0	0·2	0·7	0·3	0·8	12·9

accentuates the descent of cooled air and consequently the outrushing of the squall wind. The number of days in a year on which hail may be expected is shown in *Table 8*.

Squall.—Constant fluctuations in any wind due to local obstructions or surface friction are called *gusts*. A sudden increase of wind speed by at least 3 stages on the Beaufort scale, the speed rising to force 6 or more, and lasting for at least one minute, is called a squall. When associated with the passage of a thunderstorm it is often described as a *thunder-squall*. A squall is frequently, but not necessarily, accompanied by a temporary change in wind direction. The most important squalls from the point of view of airmen are the *line-squalls* which are usually associated with a series of thunderstorms along a line, sometimes more than a hundred miles in length. In a linesquall, the sudden increase in wind speed is invariably accompanied by a rapid shift in wind-direction, a marked rise in barometric pressure and an abrupt drop in temperature. Heavy showers of rain or hail generally accompany the passage of a line squall whose advent, under favourable conditions, is heralded by a long roll of dark clouds. The line squall or the *roll-cloud* is characterised by violent vertical currents and turbulent motions up to about 2 km. above ground with the usual vertical currents of the thunderstorm clouds extending some times up to 6 km. or more.

Nor'westers.—During the hot weather, Bengal and Orissa are occasionally visited by a type of severe thunderstorms known as Nor'westers. They are locally described as *Kal-Baisakhi* or the 'fateful thing' of the month of Baisakh (April 15—May 15). These storms usually approach a station from the north-west and burst suddenly with great fury, raising clouds of dust.

The following is a brief description of a typical Nor'wester storm :—

"The first sign of these storms is a low bank of dark clouds in the north-west, the upper outline of which has the appearance of an arch. It approaches at first slowly, and then more and more rapidly and arrives with a strong gust or squall. There is frequently thunder and lightning followed by downpours of rain and sometimes hail, which is driven by the strong winds. On some occasions the wind blows with almost hurricane force. The greatest velocity of the wind recorded in one of the storms was 185 km. per hour. These storms commence generally in the afternoon, rarely last more than three or four hours, and are usually followed by cool and clear weather during the remainder of the night."

Vertical movements in a Nor'wester are likely to be and often are violent and exceedingly irregular.

Cloud-bursts.—The ascending current in a thunderstorm, if of sufficient velocity, is able to support a large quantity of accumulated water or hail in it. If the upward current suddenly fails or is considerably reduced in velocity the suspended water is no longer supported and therefore comes down in torrents, resulting in exceptionally heavy rainfalls in a very short time. Such cloud bursts occur mostly in hilly or mountainous districts.

Dust-devils and dust-storms.—There are two types of dust-raising winds which should be distinguished from each other, namely, dust-devils and dust-storms or sandstorms. On sunny days, a small whirl-wind may be formed over a dry sandy region as a consequence of strong convection, which carries up dust into the air with it. These are known as dust-devils and they have been observed to rotate both in the clock-wise and counter-clockwise directions. The heights vary considerably in different dust-devils; in some cases in India they are said to reach as high as 600 to 900 metres. Their diameters are small and of the order of 10 metres only. Their speed of movement varies considerably ; it may be as low as 6km. an hour, or it may be as high as 50km. an hour.

While the dust-devil or sand pillar is an isolated eddy carrying dust or sand, sandstorms or dust-storms are much more extensive disturbances, being essentially dust or sand carried by strong winds over considerable areas. They may be due to :—

(*a*) an instability centre or cold front in a dry dusty land ; or

(*b*) strong winds associated with a steep barometric gradient.

The former type is akin to a thunderstorm or line-squall and has a similar duration ; the latter type may last from 9 A.M. to 5. P.M. and cover a very large area.

Strong gusty winds carrying sand and dust from far off regions, reducing the visibility considerably, occur during the summer months over the Persian Gulf and Mekran due to intensification of the seasonal low pressure over the region Persian Gulf to N. W. India. Dust-storms have been known to form during the passage of cold fronts of an advancing western depression in Iraq, in Persian Gulf and Mekran and also in northern India and to extend sometimes to a height of 3km.

The strong westerly winds of the hot weather afternoons in the Gangetic plain often raise clouds of dust with which the whole lower atmosphere becomes surcharged and which gives a peculiar reddish yellow glare to the sunlight.

CHAPTER 4.

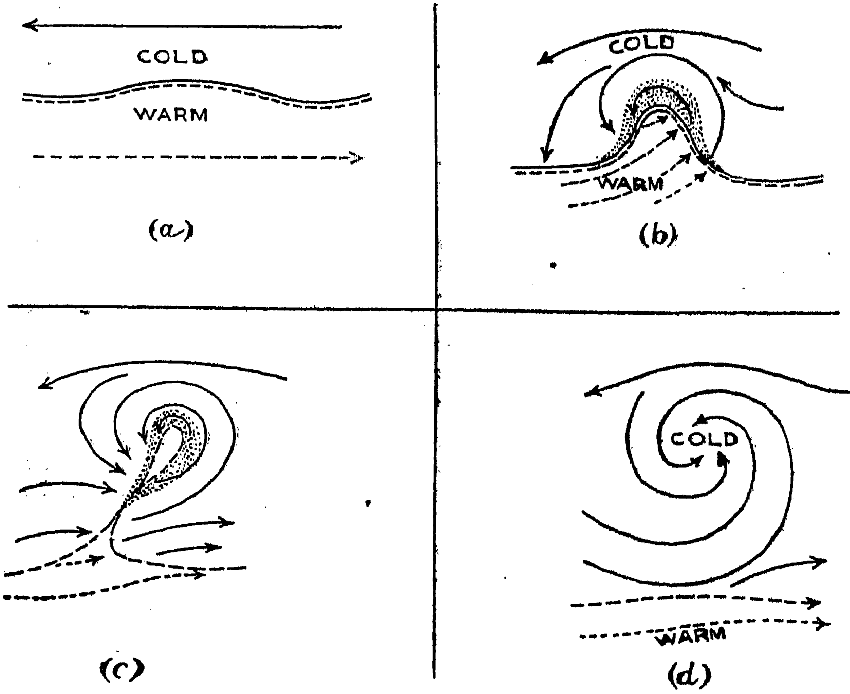
CYCLONIC DEPRESSIONS AND CYCLONIC STORMS.

Definitions.—A cyclonic depression is a region of low pressure, having a system of winds blowing round the centre in an anti-clockwise direction in the northern hemisphere and clockwise in the southern (Buys-Ballot's Law). A depression appears on a weather chart as a series of closed isobars or lines of equal barometric pressure, with the lowest pressure in the centre. The cyclonic winds on the ground have a tendency to turn inwards toward the low-centre at an angle of about 20° to 40° across the isobars; and their force depends upon the steepness of the pressure gradient, that is, upon the closeness of the isobars.

Technically " depressions " include all cyclonic circulations, ranging from those of small barometric depth and weak circulation up to the severest cyclonic storm with a ring of hurricane winds and central barometric deficiency of, perhaps, two inches of mercury or more. In practice, the India Meteorological Department tries to limit the use of the word " depression " to those cyclonic circulations in which the wind does not reach gale force ; the "depression" becomes a " cyclonic storm " when the wind in a part of the cyclonic area rises to gale force (force 8 on the Beaufort Scale); when it rises to force 10, with occasional hurricane squalls, the storm is described as severe. A fully developed severe cyclonic storm consists of four parts: (1) a calm centre, about 15 to 30 km. in diameter ; (2) an inner ring of hurricane winds of 50 to 150 km. in diameter, within which the pressure fall is excessively steep ; (3) an outer storm area, within which the winds are of gale* force or stonger and which is generally eccentrically situated with regard to the barometric centre ; and (4) an outermost area of weak cyclonic circulation.

Western depressions.—During the period November to May a series of depressions enters northern India from the west. Some of these western depressions can be traced to their origin in the Mediterranean Sea. Others appear to be secondaries formed over Arabia or Persia under the influence of the primary cyclones to the west of this region.

The structure of an active western depression is similar to that of the extra-tropical cyclones of the European countries and is illustrated in *Fig. 19.*



(a) (b) (c) (d)

The two air masses that feed the cyclone are : (1) a warm moist current of south or south-west winds in the 'warm sector' and (2) a comparatively cold and dry current of south-east or east winds in the front, and of north or north-west winds in the rear of the 'cold sector'. Along the 'warm front' the light moist air rises gently over the cold air resulting in considerable cloudiness and continuous drizzle or rain over an extended area in front of the cyclone. The cloudiness associated with the approach of the 'warm front' begins with cirrus and cirrostratus and changes through altostratus to stratus and nimbus with the passage of the 'warm front' over the observing station. Along the 'cold front,' the warm moist air is undercut and lifted up by the cold heavy air acting as a sort of wedge. This forced ascent of moist air results in the formation of cumuliform clouds over a narrow belt along the 'cold front'. The passage of a 'cold front' may, therefore, be characterised by such convectional disturbances as squalls, thunderstorms, duststorms and heavy showers of short duration or the so-called 'clearing up' showers, followed by lower temperature and a clear sky. Most of the western depressions that enter India have a feeble cyclonic circulation in the lower levels because they become "occluded" during their passage through the highlands of Persia and Afghanistan. Those depressions which take a more southerly course and enter India through the Mekran-Baluchistan coast are found often to develop marked cold and warm front phenomena.

The average number of western depressions that enter India in different months are :——

Nov.	Dec.	Jan.	Feb.	March.	April	May.
2	4	5	5	5	5	2

After crossing the Indian frontier some of the western depressions move in a north-easterly direction to the western Himalayas, others take a more easterly course and travel as far east as Assam and north Burma. The rainfall in the plains of northern India associated with the western disturbances is usually of light to moderate intensity but the snowfall on the frontier hills and the western Himalayas is often very heavy. The western depressions are also directly or indirectly responsible for the occurrence in northern India of occasional heavy fogs in winter and of most of the severe local storms of the hot weather.

Eastern depressions of the rains.—During the full prevalence of the wet monsoon a series of cyclonic depressions or storms form at the head of the Bay of Bengal to the north of Lat. 18° and travel in a north-westerly or westerly direction across the country to north-west India. The south-west monsoon is not a steady air current but on the contrary undergoes a series of pulsations. An active advance of the rain bearing winds is followed by a temporary break and then another active advance follows. The depressions or storms of the rains usually form in front of a fresh advance of the monsoon current after a break and, as they march across the coast into the interior, they carry very low clouds and heavy rain with them.

The cyclonic storms of the rains are usually of small intensity as measured by the barometric depression at the centre, which is seldom more than three or four-tenths of an inch below the normal pressure of the period. They have rarely the calm centre and the ring of hurricane winds, that characterise the severe cyclone. In the majority of monsoon storms strong cyclonic winds are experienced only at sea in the south and south-east quadrants. Nevertheless, the heavy bank of low clouds, the torrential blinding rain and local

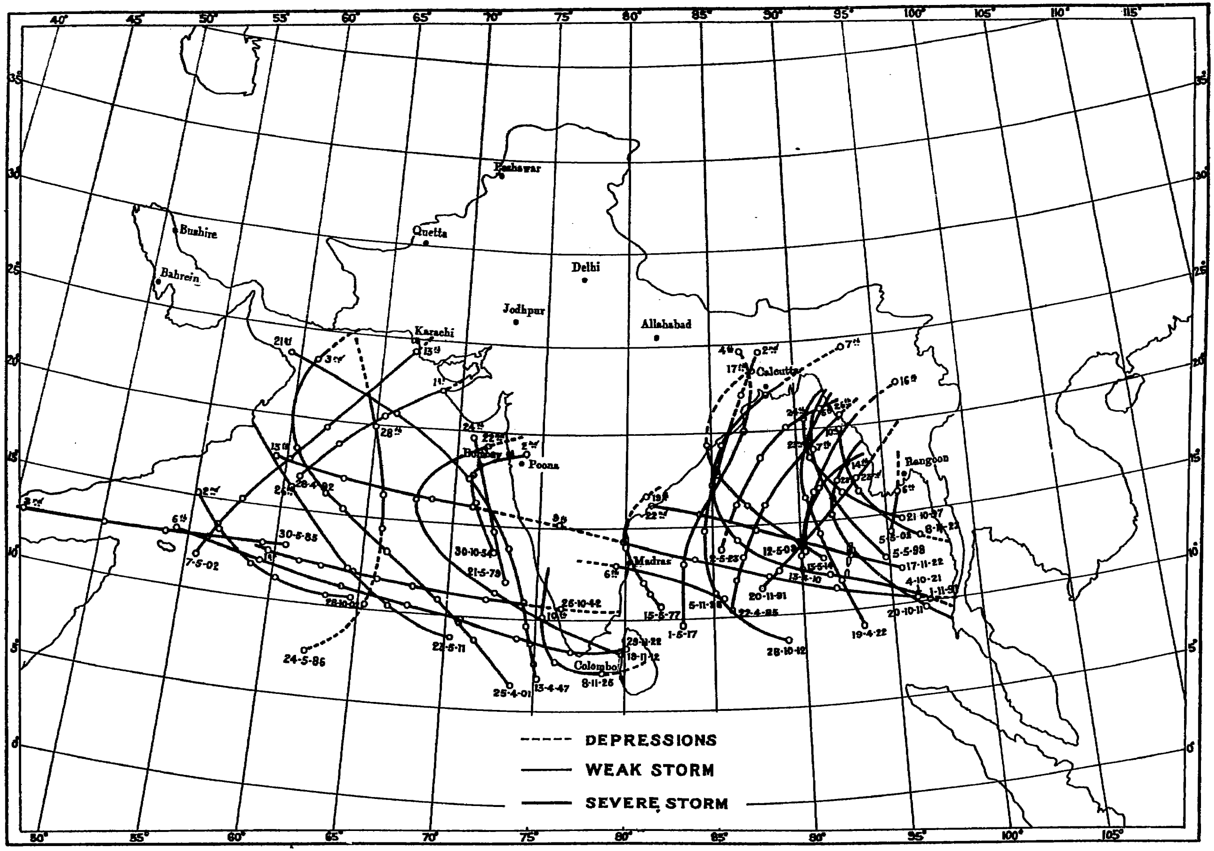


FIG. 20. TYPICAL STORM TRACKS.—APRIL, MAY, OCTOBER AND NOVEMBER.

Plate 16.

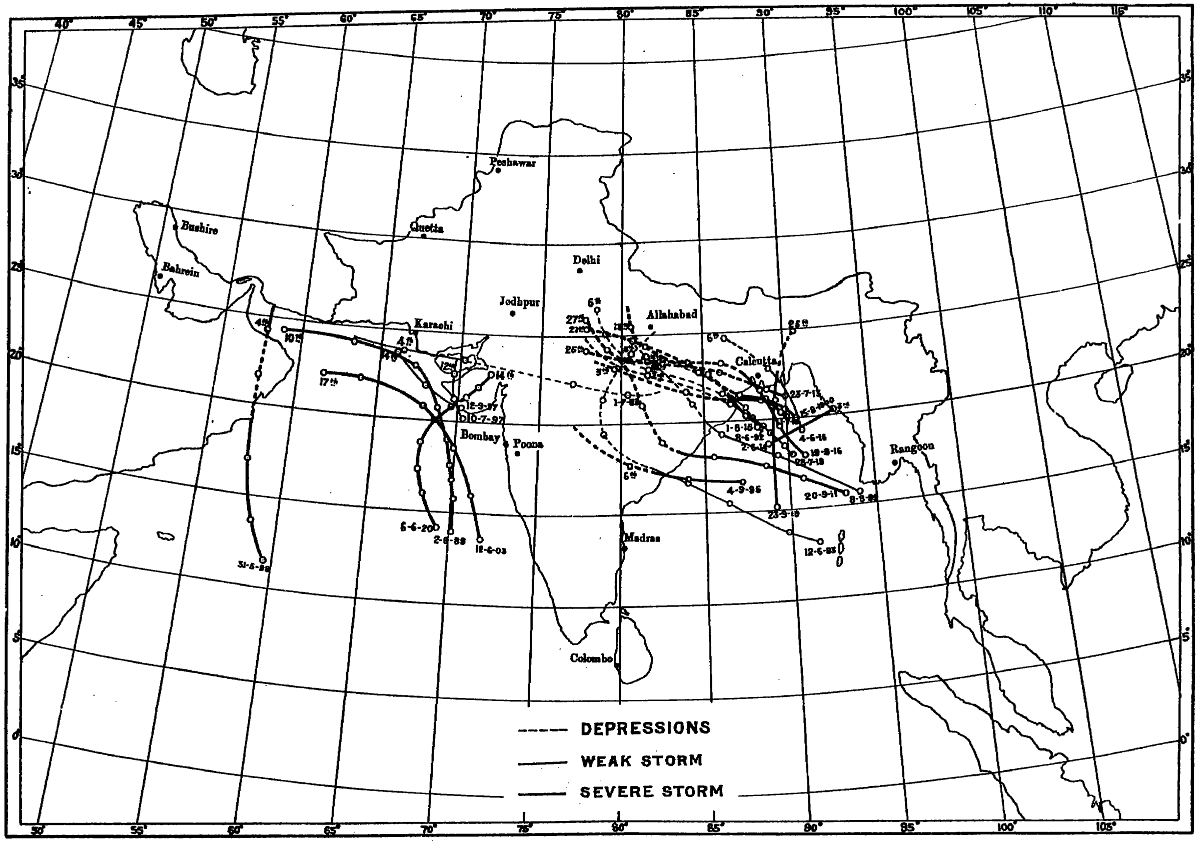


FIG. 21. TYPICAL STORM TRACKS.—JUNE TO SEPTEMBER.

severe rain squalls often associated with these depressions constitute a source of danger to airmen flying through them.

The frequency of eastern depressions from the Bay of Bengal in the rains proper is 3 or 4 per month. During the full prevalence of the south-west monsoon, cyclonic depressions are practically unknown in the Arabian Sea, but the eastern depressions occasionally travel as far west as Sind and cause disturbed weather in the north Arabian Sea off the Sind-Kathiawar Coast. A small percentage of the storms in the Indian seas in the monsoon and the post-monsoon months have been identified with typhoons in the China Seas, which have travelled westwards over Indo-China, Siam and Burma and entered the Bay of Bengal.

Cyclonic storms of the transition seasons.—The cyclones which form in the Bay of Bengal and the Arabian Sea in the transition periods (April-June and October-December) are generally of great intensity and often have an inner area of hurricane winds and a calm centre. In the severest cyclones the barometer at the centre may fall by as much as two inches below the normal pressure. Apart from the exceptionally violent winds in the inner storm area these cyclones are usually accompanied by very rapid and dangerous shifts of wind, blinding rain, and terrific squalls. Another important feature of these cyclones over the sea is the piling up in the inner storm area of a mass of water which advances with the storm and strikes the coast as a "storm wave", occasionally resulting in flooding of the low coastal districts in a few minutes to the depth of 10, 20 or even 30 feet above the tidal high-water level. Such inundations have occurred at intervals, during the past century, on the Madras and Arakan coasts, up the Hoogly and up the river Meghna, with disastrous suddenness.

On an average, 1 or 2 severe cyclones may be expected to form in the Indian seas in the pre-monsoon period and 2 or 3 in the post monsoon period. The percentage frequency of severe cyclones in the Indian seas are given below :—

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Bay of Bengal	0	0	2	8	18	5	3	2	8	22	24	8
Arabian Sea	0	0	0	10	20	23	0	0	0	15	26	6

Typical tracks of severe cyclones in the Indian Seas are exhibited in *Fig. 20—21.* For more complete information reference may be made to "Storm Tracks in the Arabian Sea", 1926, and "Storm Tracks in the Bay of Bengal", 1925, published by the India Meteorological Department.

CHAPTER 5.

CLOUDS.

Formation.—At any temperature, air can contain only a definite amount of moisture in invisible form, the amount being large when the temperature is high, and small when it is low. An air mass may or may not contain this maximum amount of moisture, but if for some reason or other it rises it cools ; and if the ascent is sufficiently large to lower its temperature below a certain critical point, called the dew-point, the water-vapour contained in the air is partly condensed into fine particles in the form of cloud. If the process of cooling is continued, more water-vapour is condensed to form larger drops which fall as rain. The ascent of moist air to form cloud and rain may be due to a variety of causes of which the most important are : (1) forced ascent of damp air over mountain ranges on the windward side, (2) gradual up-glide or mechanical uplift of light moist air over an under-running current of relatively denser air and (3) vertical convection due to thermal instability caused by heating of the lower layers of air or by a cooling of the upper layers or by a combination of both.

Types.—Below are given brief descriptions of the ten main types of cloud recognised internationally (*Figs. 22—23*).

(1) *Cirrus* (*C*).—Detached clouds of delicate and fibrous appearance without shading, generally white in colour, often of a silky or feathery appearance. Cirrus clouds take the most varied shapes, such as isolated tufts of hair (*i.e.*, thin filaments on a blue sky), branched filaments of feathery form straight or curved filaments ending in tufts, or others.

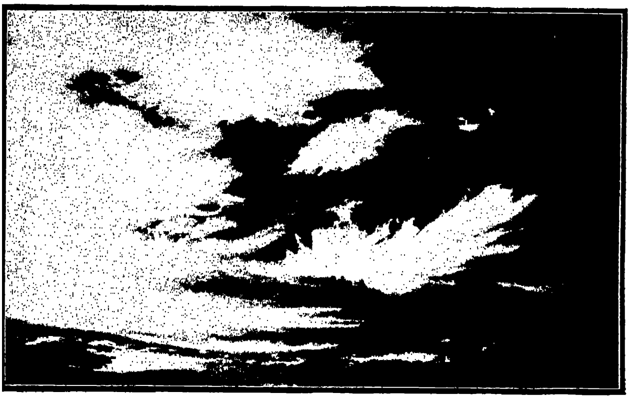
(2) *Cirrostratus* (*CS*).—Thin sheets or veils of whitish cloud which do not blur the outlines of the sun or moon, but often give rise to haloes. The sheet sometimes covers the whole sky giving it a milky appearance. It is then called *cirrus haze.* At other times, it has tangled or web-like structures or appears to be made up of a number of separate banks. All solar haloes of angular radius of about 22° show the colour of the rainbow, but in the reverse order, the red being along the innermost edges and the violet along the outermost. Lunar haloes generally show only one colour, bluish white. A corona or coronae also sometimes occur in cirrostratus. These are sets of concentric coloured rings of variable angular radius in which the violets are innermost and the reds outermost. A halo differs from a corona in its formation, in that the halo is due to refraction of light through ice-crystals, while the corona is produced by diffraction of light by water-drops.

(3) *Cirrocumulus* (*CK*).—Layers, patches or bands consisting of small white flakes or very small globular masses of semi-transparent clouds, without shadows, and brilliantly white when lighted up by the sun. The cloudlets are generally arranged in groups, or lines, or form ripples resembling those of the sand of the sea-shore.

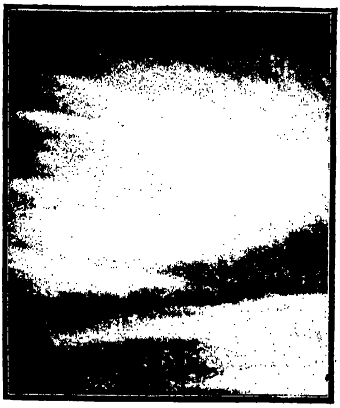
(4) *Altocumulus* (*AK*).—A layer or patches composed of laminae or rather flattened globular masses, the smallest elements of the regularly arranged layers being fairly small and thin with or without shading. These elements are arranged in groups, lines or waves in one or two directions and are sometimes so close together that their edges meet. When the edge of the cloud passes close to the sun or moon, coronae are seen, usually in lighter formations.

(5) *Altostratus* (*AS*).—Streaked or fibrous veil, more or less grey or bluish in colour. This cloud is like thick cirrostratus but without halo phenomena. The sun or moon shows through it vaguely with a faint gleam as though through a ground glass. Coronae about the sun or moon often form in light altostratus sheets.

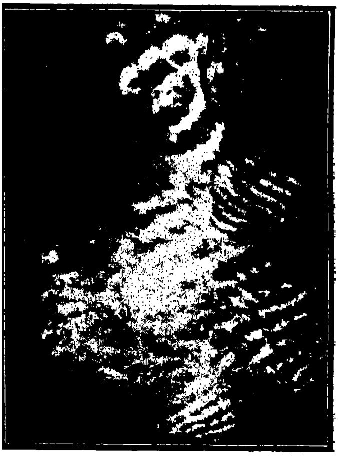
Plate 17.



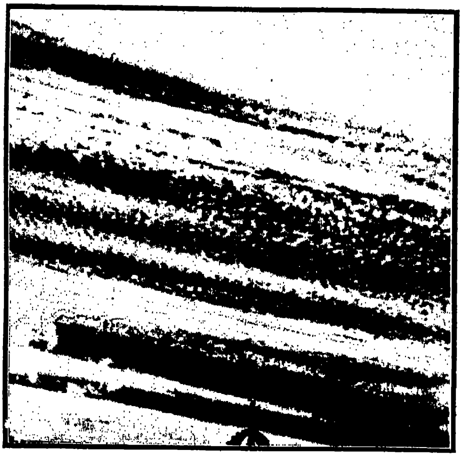
i.—Cirrus.



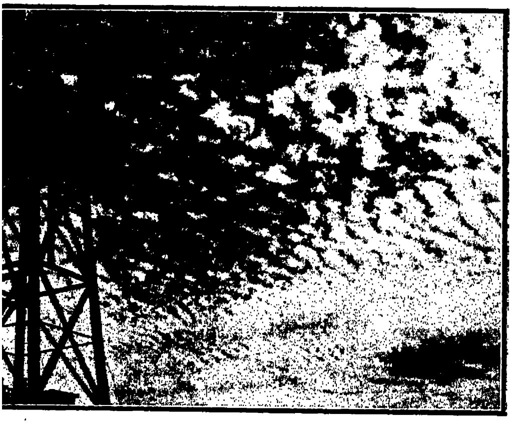
ii. Cirrostratus.



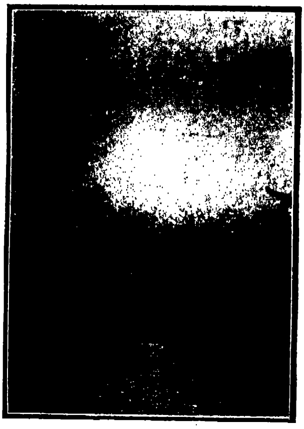
iii.—Cirrocumulus.



iv.—Cirrocumulus.



v.—Altocumulus.

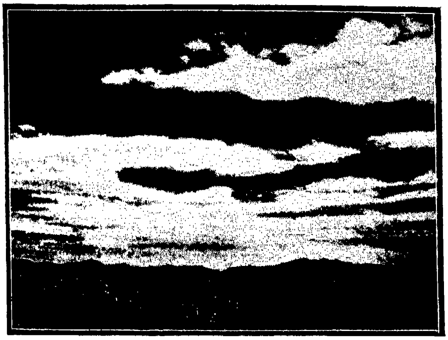


vi.—Altostratus.

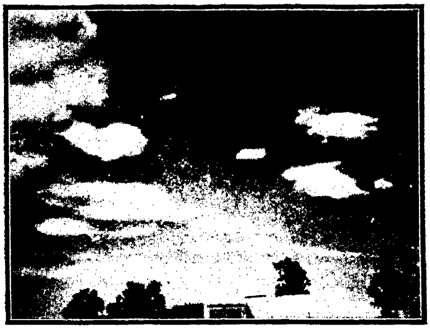
Fig. 22. Typical Cloud Forms.

Extr. Departmental Cloud Atlas,

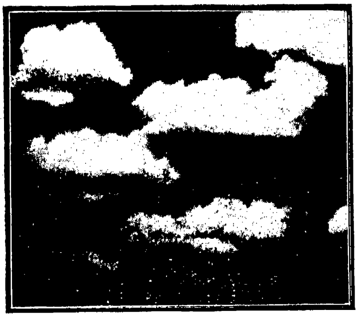
Photographs iii and iv by courtesy of Capt. C. J. P. Cave, England, and Mr. G. A. Clarke, Scotland, respectively.



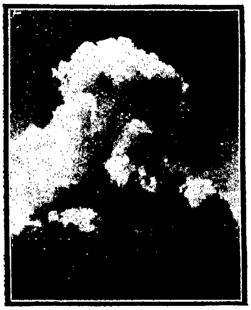
vii—Stratocumulus



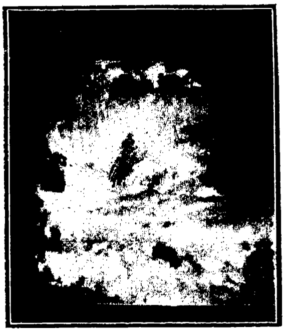
viii—Stratocumulus



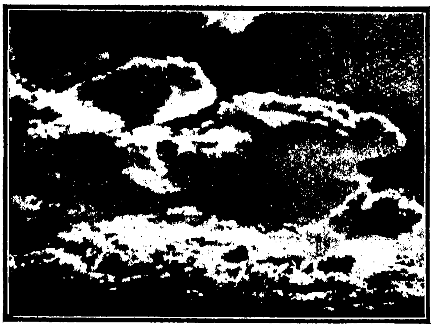
ix—Cumulus



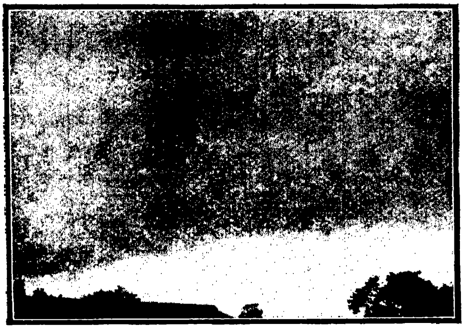
x—Cumulus



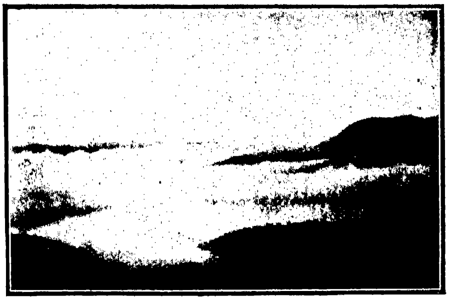
xi—Cumulonimbus



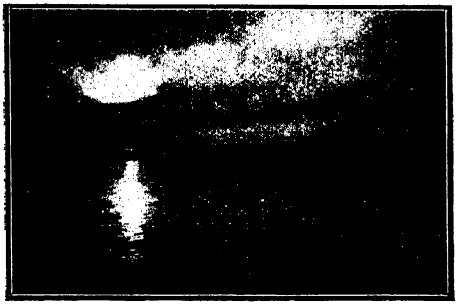
xii—Cumulonimbus



xiii—Nimbostratus



xiv—Stratus



xv—Stratus

Fig. 23. Typical Cloud Forms.

(6) *Stratocumulus* (*SK*).—Layer or patches composed of laminae or globular masses; the smallest of the regularly arranged elements are fairly large; they are soft and grey, with darker parts. Sometimes this cloud form has the characteristic appearance of great rolls of cloud arranged in parallel lines, close together. The rolls themselves are dense but in the intervening spaces the cloud is lighter, and blue sky may sometimes be seen through them. When the rolls are very close to one another, the cloud may appear as a sheet with a wavy under-surface. Stratocumulus is usually associated with the cooler times of the day (evening, night and early morning), and can often be observed forming towards evening by the flattening out and forming into layers of cumulus clouds. The reverse process takes place in the early mornings, the stratus and stratocumulus lying over plains and valleys gradually rise (as the air warms up and convection sets in) and lose their flatness, turning into cumulus.

(7) *Cumulus* (*K*).—Thick clouds, with vertical development, whose upper surfaces are dome-shaped and exhibit protuberances, while the bases are generally horizontal. These clouds are formed by ascensional movements, and constant turbulent movements can be easily observed within them. They may appear brilliant white, or with slight shadows underneath, or dark with "silver lining" round their edges, according to their position with regard to the sun. When light falls sideways, as is usually the case, cumulus clouds show deep shadows. When cumulus clouds are torn asunder by strong winds or are dissolving, so that their margins become ragged and thin, and fragments can be seen floating away from them, the clouds should be described as *fractocumulus* (*FK*). Typical cumulus develops in the morning on clear days due to strong convection, grows, and finally dissolves in the evening or flattens into stratocumulus.

(8) *Cumulonimbus* (*KN*).—Heavy masses of cloud with great vertical development whose cumuliform summits rise in the form of mountains or towers which, later, often develop a fibrous and flattened structure resembling anvils. At the base is the dark formless nimbus or drifting "scud" from which showers of rain or snow (occasionally of hail or soft hail) are falling, often accompanied with thunder and lightning. At the top a cap of fibrous texture called "false cirrus" is often seen.

(9) *Nimbostratus* (*NS*).—A low, structureless, rainy layer of dark grey colour and nearly uniform, feebly illuminated seemingly from inside. When it gives precipitation, it is in the form of continuous rain or snow. Cirrostratus or altostratus is often visible through the openings in these clouds. If a layer of nimbus separates up in strong wind into shreds, or if small loose clouds are visible floating underneath a large nimbus, the cloud may be described as fractonimbus ("scuds" of sailors).

(10) *Stratus* (*S*).—A uniform horizontal layer of low cloud resembling fog. It has the appearance of a layer of mist or fog lifted well above the ground. When broken up into irregular shreds by wind or by tops of hills, it is called *fractostratus* (*FS*).

Height.—The different forms of clouds are grouped in the following table according to their average heights:—

High Clouds (above 8 km.) .	*Average height.*
Cirrus (C) Cirrostratus (CS) Cirrocumulus (CK)	10 km.
Medium Clouds (between 3 km. and 6 km.)	
Altocumulus (AK) Altostratus (AS)	3 km. to 6 km.
Low Clouds (below 3 km.)	
Stratocumulus (SK)	below 3 km.
Nimbostratus (NS)	base : ground level to 2 km.
Cumulus or Fractocumulus (K or FK)	base : 1·5 km. ; top : 2 km. to 3 km.
Cumulonimbus (KN)	base : 1·5 km. ; top : 3 km. to 8 km.
Stratus or Fractostratus (S or FS)	below 800 metres.

Thickness.—Below is given a very rough indication of the average thickness of low clouds :—

Cloud.	*Average thickness.* (Metres.)
Stratocumulus	About 500
Cumulus	„ 700
Cumulonimbus	„ 7000
Nimbus	„ 800
Stratus	„ 300

The thickness of cumulonimbus clouds on individual occasions may, however, be as great as 8 to 10 km.

In practical flying very little importance is attached to medium and high clouds whose altitudes lie above 3 kilometres. All interest is centred in the heights of low clouds. The bases of stratocumulus and cumulus clouds are rarely below 1,000 metres but the base of a cumulonimbus cloud may be occasionally lower than 700 metres. In the case of stratus and nimbus, the cloud ceilings have frequently been observed to be within only a few hundred feet of the average ground level. In mountainous regions such as the Western Ghats of Bombay and the coastal ranges of Burma, the cloud ceilings in the rains are often dangerously near or cover the mountain tops and blind flying through clouds has to be resorted to, if the hills have to be crossed.

In *Table 9* have been given certain data relating to the base of low clouds at important stations along the air-routes. These data were compiled from observations of pilot balloons, which became invisible in low clouds, during a period of about 5 years at each station. It will be clear that such data cannot give very accurately the height of base, particularly when the clouds are diffused near their base. In the table, the data have been arranged so as to indicate the percentge number of occasions, the balloons became invisible in clouds below certain heights. The figures, therefore, give the chance of the ground being invisible if a pilot choose to fly at a particular height.

The average heights of the different types of clouds over various parts of India have been shown in *Fig. 24.*

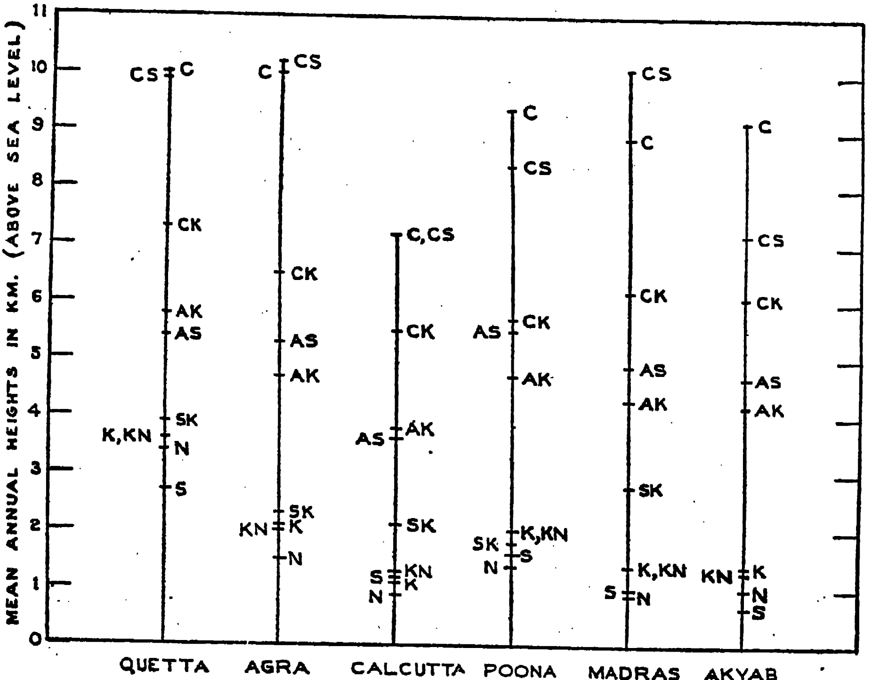


TABLE 9.

HEIGHT OF BASE OF LOW CLOUDS.

January (Morning).

(Percentage number of days in a month on which balloon became invisible in cloud, rain, fog or dust below selected heights.).

Name of Station.	Altitude (Feet).	Height in metres above station level.									No ascent.		Years for which data have been used.
		Above 3000.	Below 3000.	Below 2500.	Below 2000.	Below 1500.	Below 1000.	Below 500.	Below 300.	Below 150.	Rain, fog and dust.	Other causes.	
Bahrein	8	58·5	40·6	27·7	21·9	10·3	4·5	0	0	0	4·5	1·3	1928—32
Gwador	22	61·9	29·0	21·9	17·4	12·3	4·5	0	0	0	1·9	7·1	1928—32
Karachi (Drigh Road)	77	88·4	11·6	9·0	4·5	3·9	1·3	0	0	0	0	0	1928—32
Ajmer	1611	91·9	7·3	4·8	0·8	0·8	0·8	0	0	0	0	0·8	1929—32
Delhi	719	75·8	16·1	11·3	4·8	3·2	1·6	1·6	0	0	1·6	6·5	1930—31
Agra	554	81·9	12·3	7·1	2·6	1·3	0·6	0	0	0	3·9	1·9	1928—32
Allahabad	309	62·9	35·5	22·6	8·1	0	0	0	0	0	1·6	0	1931—32
Jubbulpore	1289	91·1	5·6	3·2	1·6	0·8	0·8	0	0	0	0·8	2·4	1929—32
Patna	173	91·9	5·6	3·2	0·8	0·8	0	0	0	0	2·4	0	1929—32
Sambalpur	486	96·8	3·2	3·2	1·6	1·6	1·6	1·6	0	0	0	0	1931—32
Calcutta	21	70·3	20·0	14·2	9·0	3·9	1·9	0	0	0	3·9	5·8	1928—32
Dacca	30	71·8	19·4	12·9	4·8	3·2	2.4	0	0	0	6·5	2·4	1929—32
Tezpur	258	59·1	24·7	16·1	9·7	6·5	2·2	1·1	0	0	14·0	2·2	1929—31
Mandalay	252	95·2	4·8	0·8	0·8	0	0	0	0	0	0	0	1929—32
Akyab	20	87·1	11·0	7·7	3·2	0·6	0·6	0	0	0	0·6	1·3	1928—32
Rangoon	18	80·6	7·3	2·4	0	0	0	0	0	0	1·6	10·5	1929—32
Ahmedabad	163	94·4	3·2	1·6	0·8	0	0	0	0	0	0·8	1·6	1929—32
Poona	1834	98·6	0·7	0	0	0	0	0	0	0	0	0·7	1928—32
Hyderabad (Dn.) (Begumpet)	1709	9[illegible]·8	2·2	2·2	2·2	2·2	2·2	0	0	0	0	0	1930—32
Bangalore	3021	72·3	26·5	24·5	17·4	11·0	7·7	2·6	0	0	0	1·3	1928—32
Madras	22	66·5	32·3	27·1	20·6	14·8	6·5	0·6	0	0	0	1·3	1928—32
Waltair	126	86·5	9·7	7·3	5·6	3·2	2·4	0	0	0	0	4·0	1929—32
Trivandrum	200	...	...	...	...	...	...	...	...	...	...	...	...
Quetta	5405	30·3	62·6	43·2	24·5	13·5	7·7	0·6	0	0	5·8	1·3	1928—32
Peshawar	1164	81·9	14·8	12·3	9·7	7·1	3·2	0·6	0	0	2·6	0·6	1928—32
Lahore	702	83·9	14·2	6·5	5·2	2·6	0·6	0	0	0	0	1·9	1928—32

TABLE 9—(*contd.*)

HEIGHT OF BASE OF LOW CLOUDS.

January (Afternoon).

(Percentage number of days in a month on which balloon became invisible in cloud, rain, fog or dust below selected heights.)

Name of Station.	Altitude (Feet).	Height in metres above station level.									No ascent.		Years for which data have been used.
		Above 3000.	Below 3000.	Below 2500.	Below 2000.	Below 1500.	Below 1000.	Below 500.	Below 300.	Below 150.	Rain, fog and dust.	Other causes.	
Bahrein . .	8	65·6	31·2	21·5	12·9	4·3	3·2	0	0	0	3·2	0	1930—32
Gwador . .	22	63·4	25·8	24·7	18·3	8·6	3·2	0	0	0	3·2	7·5	1930—32
Karachi (Drigh Road) . .	77	79·4	16·8	11·0	5·8	1·9	1·3	0	0	0	0	3·9	1928—32
Ajmer . . .	1611	75·8	22·6	8·1	1·6	0	0	0	0	0	0	1·6	1931—32
Delhi . .	719	88·7	9·7	4·8	3·2	1·6	0	0	0	0	0	1·6	1930—31
Agra . . .	554	84·9	14·0	6·5	4·3	2·2	0	0	0	0	0	1·1	1930—32
Allahabad . .	309	77·4	22·6	14·5	6·5	0	0	0	0	0	0	0	1931—31
Jubbulpore . .	1289	93·5	6·5	1·6	0	0	0	0	0	0	0	0	1931—32
Patna . . .	173	82·3	17·7	8·1	0	0	0	0	0	0	0	0	1931—32
Sambalpur . .	486	96·8	3·2	1·6	1·6	0	0	0	0	0	0	0	1931—32
Calcutta . .	21	93·5	6·5	3·2	3·2	1·1	0	0	0	0	0	0	1930—32
Dacca . . .	20	84·9	10·8	8·6	3·2	1·1	0	0	0	0	1·1	3·2	1930—32
Tezpur . .	258	...	...	...	...	...	...	...	...	...	...	...	...
Mandalay . .	252	98·4	1·6	0	0	0	0	0	0	0	0	0	1931—32
Akyab . .	20	71·0	21·0	14·5	8·1	4·8	0	0	0	0	0	8·1	1931—32
Rangoon . .	18	77·4	21·0	14·5	9·7	0	0	0	0	0	0	1·6	1931—32
Ahmedabad .	163	91·9	4·8	1·6	1·6	0	0		0	0	0	3·2	1931—32
Poona . . .	1834	...	...	...	...	...	...	...	...	...	...	...	...
Hyderabad (Dn.) (Begumpet) .	1709	...	...	...	...	...	...	...	...	...	...	...	...
Bangalore . .	3021	...	...	...	...	...	...	...	...	...	...	...	...
Madras . .	22	...	...	...	...	...	...	...	...	...	...	...	...
Waltair . .	126	90·3	3·2	0	0	0	0	0	0	0	0	6·5	1931—32
Trivandrum .	200	...	...	...	...	...	...	...	...	...	...	...	...
Quetta. . .	5405	32·9	54·2	38·7	22·6	16·8	5·8	0 6	0	0	9·0	3·9	1928—32
Peshawar . .	1164	88·2	11·8	9·7	7·5	4·3	2·2	1·1	0	0	0	0	1930—32
Lahore . .	702	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 9—(*contd.*)

HEIGHT OF BASE OF LOW CLOUDS.

April (Morning).

(Percentage number of days in a month on which balloon became invisible in cloud, rain, fog or dust below selected heights.)

Name of Station.	Altitude (Feet).	Height in metres above station level.									No ascent.		Years for which data have been used.
		Above 3000.	Below 3000.	Below 2500.	Below 2000.	Below 1500.	Below 1000.	Below 500.	Below 300.	Below 150.	Rain, fog and dust.	Other casues.	
Bahrein	8	54·0	40·0	30·0	18·7	16·0	6·7	0	0	0	4·0	2·0	1928—32
Gwador	22	70·0	25·3	18·7	15·3	8·0	4·7	0·7	0	0	1·3	3·3	1928—32
Karachi (Drigh Road)	77	78·7	21·3	16·7	14·0	10·7	5·3	0·7	0	0	0	0	1928—32
Ajmer	1611	79·2	18·3	10·8	5·0	1·7	0	0	0	0	0	2·5	1929—32
Delhi	719	78·3	21·7	15·0	10·0	3·3	0	0	0	0	0	0	1930—31
Agra	554	73·3	24·7	14·7	7·3	0·7	0	0	0	0	0	2·0	1928—32
Allahabad	309	58·9	41·1	22·2	10·0	3·3	0	0	0	0	0	0	1930—32
Jubbulpore	1289	91·7	4·2	1·7	0·8	0·8	0	0	0	0	0·8	3·3	1929—32
Patna	173	67·5	32·5	22·5	15·0	12·5	5·0	0	0	0	0	0	1929—32
Sambalpur	486	95·0	5·0	0	0	0	0	0	0	0	0	0	1931—32
Calcutta	21	54·7	35·3	24·7	17·3	12·7	8·7	1·3	0	0	0	10·0	1928—32
Dacca	30	35·8	60·8	54·2	47·5	35·0	28·3	6·7	0·8	0	3·3	0	1929—32
Tezpur	258	27·8	45·6	33·3	21·1	11·1	5·6	1·1	1·1	0	10·0	16·7	1929—31
Mandalay	252	75·0	25·0	17·5	8·3	3·3	0	0	0	0	0	0	1929—32
Akyab	20	63·3	33·3	26·0	13·3	8·0	3·3	0	0	0	2·0	1·3	1928—32
Rangoon	18	75·0	22·5	17·5	13·3	9·2	4·2	0	0	0	0	2·5	1929—32
Ahmedabad	163	90·0	7·5	5·0	2·5	0·8	0·8	0	0	0	0	2·5	1929—32
Poona	1834	94·0	3·3	1·3	0·7	0	0	0	0	0	0	2·7	1928—32
Hyderabad (Dn.) (Begumpet)	1709	95·6	3·3	3·3	2·2	1·1	0	0	0	0	0	1·1	1930—32
Bangalore	3021	66·0	32·7	19·3	16·0	10·0	6·7	0·7	0	0	0	1·3	1928—32
Madras	22	82·0	14·0	13·3	8·7	5·3	0·7	0	0	0	0·7	3·3	1928—32
Waltair	126	71·7	25·0	21·7	15·8	13·3	7·5	0	0	0	0	3·3	1929—32
Trivandrum	200	68·3	26·7	20·0	13·3	5·0	0	0	0	0	2·5	2·5	1929—32
Quetta	5405	58·0	40·7	24·7	7·3	2·7	0	0	0	0	0	1·3	1928—32
Peshawar	1164	96·7	2·7	1·3	1·3	1·3	0·7	0·7	0	0	0	0·7	1928—32
Lahore	702	87·3	10·0	8·0	3·3	2·7	1·3	0	0	0	0	2·7	1928—32

TABLE 9—(*contd.*)

HEIGHT OF BASE OF LOW CLOUDS.

April (Afternoon).

(Percentage number of days in a month on which balloon became invisible in cloud, rain, fog or dust below selected heights.)

Name of Station.	Altitude (Feet).	Height in metres above station level.									No ascent.		Years for which data have been used.
		Above 3,000.	Below 3000.	Below 2500.	Below 2000.	Below 1500.	Below 1000.	Below 500.	Below 300.	Below 150	Rain, fog and dust.	Other causes.	
Bahrein	8	65·6	28·9	18·9	8·9	2·2	2·2	0	0	0	3·3	2·2	1930—32.
Gwador	22	75·6	20·0	12·2	5·6	2·2	0	0	0	0	0	4·4	1930—32.
Karachi (Drigh Road).	77	83·3	16·0	12·0	9·3	5·3	1·3	0	0	0	0	0·7	1928—32.
Ajmer	1611	71·7	25·0	10·0	1·7	0	0	0	0	0	0	3·3	1931—32.
Delhi	719	68·3	28·3	21·7	13·3	10·0	6·7	1·7	0	0	0	3·3	1930—31.
Agra	554	58·9	36·7	22·2	12·2	3·3	1·1	0	0	0	0	4·4	1930—32.
Allahabad	309	66·7	33·3	22·2	7·8	3·3	1·1	0	0	0	0	0	1930—32.
Jubbulpore	1289	83·3	13·3	5·0	5·0	0	0	0	0	0	0	3·2	1931—32.
Patna	173	68·3	31·7	23·3	13·3	3·3	1·7	0	0	0	0	0	1931—32.
Sambalpur	486	91·7	8·3	5·0	3·3	0	0	0	0	0	0	0	1931—32.
Calcutta	21	91·1	8·9	4·4	4·4	4·4	0	0	0	0	0	0	1930—32.
Dacca	30	48·9	42·2	38·9	30·0	21·1	13·3	3·3	0	0	6·7	2·2	1930—32.
Tezpur	258	...	...	...	...	...	...	...	...	...	...	...	...
Mandalay	252	93·3	6·7	5·0	5·0	1·7	0	0	0	0	0	0	1931—32.
Akyab	20	68·3	30·0	21·7	16·7	15·0	5·0	0	0	0	1·7	0	1931—32.
Rangoon	18	56·7	38·3	20·0	10·0	5·0	3·3	0	0	0	0	5·0	1931—32.
Ahmedabad	163	88·3	10·0	5·0	1·7	0	0	0	0	0	0	1·7	1931—32
Poona	1834	...	...	...	...	...	...	...	...	...	...	...	...
Hyderabad (Dn.) (Begumpet).	1709	...	...	...	...	...	...	...	...	...	...	...	...
Bangalore	3021	...	...	...	...	...	...	...	...	...	...	...	...
Madras	22	...	...	...	...	...	...	...	...	...	...	...	...
Waltair	126	96·7	0	0	0	0	0	0	0	0	0	3·3	1931—32.
Trivandrum	200	...	...	...	...	...	...	...	...	...	...	...	...
Quetta	5405	52·7	42·7	32·0	16·0	6·0	1·3	0	0	0	0·7	4·0	1928—32.
Peshawar	1164	90·0	8·9	5·5	1·1	1·1	1·1	0	0	0	0	1·1	1930—32.
Lahore	702	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 9—(*contd.*)

HEIGHT OF BASE OF LOW CLOUDS.

July (Morning).

(Percentage number of days in a month on which balloon became invisible in cloud, rain, fog or dust below selected heights.)

Name of Station.	Altitude (Feet).	Height in metres above station level.									No ascent.		Years for which data have been used.
		Above 3000.	Below 3000.	Below 2500.	Below 2000.	Below 1500.	Below 1000.	Below 500.	Below 300.	Below 150.	Rain, fog and dust.	Other causes.	
Bahrein . .	8	27·1	67·1	61·3	52·9	42·6	23·9	1·3	0	0	5·2	0·6	1928—32.
Gwador . .	22	31·0	66·5	63·9	59·4	52·3	42·6	1·9	0	0	1·3	1·3	1928—32.
Karachi (Drigh Road).	77	24·5	74·8	71·0	66·5	53·5	31·6	0·6	0	0	0·6	0	1928—32.
Ajmer . . .	1611	36·1	56·1	52·9	49·0	43·2	35·5	5·8	0·6	0	7·1	0·6	1928—32.
Delhi . . .	719	37·1	50·0	45·2	33·9	19·4	6·5	3·2	0	0	3·2	9·7	1930—31.
Agra . . .	554	42·6	54·2	38·1	25·8	18·7	10·3	1·9	0·6	0	2·6	0·6	1928—32.
Allahabad . .	309	26·9	67·7	62·4	50·5	38·7	21·5	2·2	0	0	5·4	0	1930—32.
Jubbulpore . .	1289	13·7	57·3	49·2	40·3	34·7	29·0	9·7	0·8	0	27·4	1·6	1929—32.
Patna . .	173	31·6	49·0	40·0	31·6	23·2	14·2	3·9	0	0	18·1	1·3	1928—32.
Sambalpur . .	486	21·5	57·0	51·6	46·2	36·6	22·6	4·3	1·1	0	18·3	3·2	1930—32.
Calcutta . .	21	27·1	60·0	52·9	44·5	34·2	22·6	6·5	0	0	11·6	1·3	1928—32.
Dacca . . .	30	3·2	69·7	66·5	56·8	47·7	40·0	7·1	0	0	27·1	0	1928—32.
Tezpur . .	258	27·4	30·6	25·8	19·4	12·9	6·5	0	0	0	38·7	3·2	1929—30.
Mandalay . .	252	37·9	56·5	48·4	39·5	16·9	7·3	0	0	0	5·6	0	1929—32.
Akyab . .	20	7·7	44·5	41·3	38·1	32·3	20·0	1·9	0	0	47·7	0	1928—32.
Rangoon . .	18	17·7	67·7	61·3	50·0	33·1	19·4	1·6	0	0	12·9	1·6	1929—32.
Ahmedabad . .	163	12·9	71·6	67·7	63·2	50·3	31·6	4·5	0	0	12·9	2·6	1928—32.
Poona . . .	1834	7·1	89·6	89·0	86·5	75·4	51·6	0·7	0·7	0	1·3	2·0	1928—32.
Hyderabad (Dn.) (Begumpet).	1709	29·0	69·9	62·4	51·6	43·0	29·0	5·4	0	0	1·1	0	1930—32.
Bangalore . .	3021	3·2	96·8	95·5	92·9	87·1	67·1	9·0	0·6	0	0	0	1928—32.
Madras . .	22	71·6	27·7	12·9	3·2	0	0	0	0	0	0	0·6	1928—32.
Waltair . .	126	29·0	56·5	46·0	34·7	20·2	7·3	1·6	0	0	8·1	6·5	1929—32.
Trivandrum .	200	28·2	66·9	53·2	38·7	30·6	12·9	0	0	0	3·2	1·6	1929—32.
Quetta. . .	5405	53·6	45·8	31·0	13·5	5·2	0	0	0	0	0	0·6	1928—32.
Peshawar . .	1104	78·7	19·4	12·3	7·7	6·5	3·9	1·3	0	0	1·3	0·6	1928—32.
Lahore . .	702	66·5	29·0	19·4	10·3	7·1	3·9	0	0	0	1·9	2·6	1928—32.

TABLE 9—(*cont.*)

HEIGHT OF BASE OF LOW CLOUDS.

July (Afternoon).

(Percentage number of days in a month on which balloon became invisible in cloud, rain, fog or dust below selected heights.)

Name of Station.	Altitude. (Feet).	Height in metres above station level									No ascent.		Years for which data have been used.
		Above 3000.	Below 3000.	Below 2500.	Below 2000.	Below 1500.	Below 1000.	Below 500.	Below 300.	Below 150.	Rain, fog and dust.	Other causes.	
Bahrein	8	14·0	81·7	76·3	62·4	36·6	17·2	1.1	0	0	1·1	3·2	1930—32.
Gwador	22	50·5	30·1	26·9	24·7	20·4	12·9	0	0	0	0	19·4	1930—32.
Karachi (Drigh Road).	77	21·3	76·8	72·3	67·1	59·4	29·0	0	0	0	1·3	0·6	1928—32.
Ajmer	1611	31·2	59·1	48·4	36·6	23·7	10·8	0	0	0	6·5	3·2	1930—32.
Delhi	719	17·7	72·6	62·9	48·4	22·6	11·3	1·6	0	0	0	9·7	1930—31.
Agra	554	34·4	63·4	50·5	36·6	18·3	10·8	2·2	0	0	2·2	0	1930—32.
Allahabad	309	28·0	65·6	54·8	36·6	11·8	3·2	0	0	0	6·5	0	1930—32.
Jubbulpore	1289	22·6	62·4	55·9	49·5	36·6	21·5	5·4	2·2	0	14·0	1·1	1930—32.
Patna	173	43·5	53·2	45·2	33·9	22·6	11·3	3·2	1·6	0	3·2	0	1931—32.
Sambalpur	486	24·7	65·6	55·9	48·4	30·1	17·2	2·2	0	0	8·6	1.1	1930—32.
Calcutta	21	29·0	58·1	48·4	40·9	28·0	7·5	1·1	0	0	11·8	1·1	1930—32.
Dacca	30	14·0	64·5	52·7	46·2	37·6	25·8	3·2	0	0	21·5	0	1930—32.
Tezpur	258	...	...	...	...	...	...	...	...	...	...	...	...
Mandalay	252	41·9	54·8	43·5	27·4	9·7	3·2	0	0	0	3·2	0	1931—32.
Akyab	20	15·1	47·3	44·1	33·3	25·8	18·3	1·1	0	0	37·6	0	1930—32.
Rangoon	18	9·7	66·7	65·6	61·3	53·8	35·5	1·1	0	0	23·7	0	1930—32.
Ahmedabad	163	22·6	62·9	61·3	50·0	25·8	4·8	0	0	0	14·5	0	1931—32.
Poona	1834	...	...	...	...	...	...	...	...	...	...	...	...
Hyderabad (Dn.) (Begumpet).	1709	...	...	...	...	...	...	...	...	...	...	...	...
Bangalore	3021	...	...	...	...	...	...	...	...	...	...	...	...
Madras	22	...	...	...	...	...	...	...	...	...	...	...	...
Waltair	126	37·6	52·7	48·4	25·8	17·2	6·5	0	0	0	5·4	4·3	1930—32.
Trivandrum	200	...	...	...	...	...	...	...	...	...	...	...	...
Quetta	5405	32·9	59·4	44·5	27·7	11·6	0·6	0	0	0	2·6	5·2	1928—32.
Peshawar	1164	90·3	8·6	7·5	4·3	1·1	0	0	0	0	1·1	0	1930—32.
Lahore	702	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 9—(*concld.*)

HEIGHT OF BASE OF LOW CLOUDS.

November (Morning.)

(Percentage number of days in a month on which balloon became invisible in cloud, rain, fog or dust below selected heights.)

Name of Station.	Altitude. (Feet).	Height in metres above station level.									No ascent.		Years for which data have been used.
		Above 3000.	Below 3000.	Below 2500.	Below 2000.	Below 1500.	Below 1000.	Below 500.	Below 300.	Below 150.	Rain, fog and dust.	Other causes.	
Bahrein	8	65·0	27·5	24·2	17·5	9·2	4·2	0	0	0	0·8	6·7	1928—31
Gwador	22	78·0	3·3	3·3	2·0	1·3	0·7	0	0	0	3·3	15·3	1927—31
Karachi (Drigh Road).	77	98·7	1·8	0·7	0·7	0	0	0	0	0	0	0	1927—31
Ajmer	1611	94·2	3·3	1·7	0·8	0·8	0·8	0	0	0	0	2·5	1928—31
Delhi	719	76·7	8·3	1·7	0	0	0	0	0	0	0	15·0	1930—31
Agra	554	87·3	10·7	6·7	4·0	2·0	1·3	0·7	0	0	0	2·0	1927—31
Allahabad	309	60·0	38·3	21·7	10·0	6·7	1·7	1·7	0	0	1·7	0	1930—31
Jubbulpore	1289	90·0	4·2	4·2	2·5	0	0	0	0	0	0·8	5·0	1928—31
Patna	173	89·2	8.3	6·7	2·5	1·7	0·8	0	0	0	2·5	0	1928—31
Sambalpur	486	83·3	13·3	11·7	10·0	6·7	6·7	0	0	0	3·3	0	1930—31
Calcutta	21	84·0	13·3	12·7	7·3	4·7	2·0	0·7	0	0	2·0	0·7	1927—31
Dacca	30	79·2	12·5	9·2	6·7	3·3	0·8	0	0	0	8·3	0	1928—31
Tezpur	258	61·7	18·3	18·3	15·0	13·3	6·7	0	0	0	20·0	0	1929—30
Mandalay	252	62·2	27·8	22·2	15·6	6·7	4·4	1·1	0	0	10·0	0	1929—31
Akyab	20	62·7	25·3	20·0	10·0	4·7	2·7	0	0	0	8·7	3·3	1927—31
Rangoon	18	74·2	12·5	6·7	4·2	1·7	1·7	0	0	0	1·7	11·7	1928—31
Ahmedabad	163	95·8	4·2	0·8	0·8	0·8	0	0	0	0	0	0	1928—31
Poona	1834	84·0	16·0	12·7	11·3	10·0	6·0	1·3	0·7	0	0	0	1928—32
Hyderabad (Dn.) (Begumpet).	1709	74·4	22·2	21·1	20·0	17·8	16·7	3·3	0	0	3·3	0	1929—31
Bangalore	3021	43·3	56·7	51·3	45·3	38·7	30·7	8·7	0	0	0	0	1927—31
Madras	22	51·3	45·3	41·3	34·7	26·0	12·7	0	0	0	2·7	0·7	1927—31
Waltair	126	75·8	17·5	14·2	11·7	8·3	0·8	0	0	0	3·3	3·3	1928—31
Trivandrum	200	48·9	36·7	28·9	18·9	16·7	10·0	0	0	0	2·2	12·2	1929—31
Quetta	5405	74·0	24·0	12·0	2·0	0·7	0	0	0	0	0	2·0	1927—31
Peshawar	1164	97·3	2·0	1·3	0·7	0	0	0	0	0	0·7	0	1927—31
Lahore	702	95·3	4·0	3·3	0·7	0·7	0	0	0	0	0	0·7	1927—31

TABLE 9—(*concld.*)

HEIGHT OF BASE OF LOW CLOUDS.

November (Afternoon.)

(Percentage number of days in a month on which balloon became invisible in cloud, rain, fog or dust below selected heights.)

Name of Station.	Altitude. (Feet.)	Height in metres above station level.									No ascent.		Years for which data have been used.
		Above 3000.	Below 3000.	Below 2500.	Below 2000.	Below 1500.	Below 1000.	Below 500.	Below 300.	Below 150.	Rain fog, and dust.	Other causes.	
Bahrein	8	76·7	16·7	12·2	2·2	0	0	0	0	0	0	6·7	1929—31
Gwador	22	84·4	1·1	1·1	0	0	0	0	0	0	1·1	13·3	1929—31
Karachi (Drigh Road).	77	88·0	6·0	3·3	3·3	1·3	0	0	0	0	0	6·0	1927—31
Ajmer	1611	96·7	0	0	0	0	0	0	0	0	0	3·3	1930—31
Delhi	719	73·3	8·3	3·3	0	0	0	0	0	0	0	18·3	1930—31
Agra	554	96·7	3·3	1·1	1·1	1·1	0	0	0	0	0	0	1929—31
Allahabad	309	81·7	18·3	10·0	1·7	1·7	0	0	0	0	0	0	1930—31
Jubbulpore	1289	90·0	8·3	5·0	3·3	1·7	1·7	0	0	0	1·7	0	1930—31
Patna	173	73·3	25·0	15·0	6·7	3·3	1·7	0	0	0	1·7	0	1930—31
Sambalpur	486	81·7	16·7	15·0	8·3	5·0	0	0	0	0	1·7	0	1930—31
Calcutta	21	78·9	16·7	12·2	11·1	6·7	4·4	1·1	0	0	4·4	0	1929—31
Dacca	30	61·1	30·0	22·2	15·6	6·7	2·2	0	0	0	8·9	0	1929—31
Tezpur	258	...	...	...	...	...	...	...	...	...	...	...	...
Mandalay	252	83·3	16·7	16·7	13·3	10·0	6·7	0	0	0	0	0	1931
Akyab	20	48·3	45·0	31·7	20·0	15·0	1·7	0	0	0	6·7	0	1930—31
Rangoon	18	50·0	45·0	35·0	20·0	10·0	0	0	0	0	1·7	3·3	1930—31
Ahmedabad	163	96·7	1.7	0	0	0	0	0	0	0	0	1·7	1930—31
Poona	1834	...	...	...	...	...	...	...	...	...	...	...	...
Hyderabad (Dn.) (Begumpet).	1709	...	...	...	...	...	...	...	...	...	...	...	...
Bangalore	3021	...	...	...	...	...	...	...	...	...	...	...	...
Madras	22	...	...	...	...	...	...	...	...	...	...	...	...
Waltair	126	61·7	28·3	23·3	18·3	11·7	3·3	0	0	0	1·7	8·3	1930—31
Trivandrum	200	...	...	...	...	...	...	...	...	...	...	...	...
Quetta	5405	68·3	25·8	13·3	3·3	0	0	0	0	0	0·8	5·0	1928—31
Peshawar	1164	98·9	1·1	1·1	0	0	0	0	0	0	0	0	1929—31
Lahore	702	...	...	...	...	...	...	...	...	...	...	...	...

Cloud motion.—Clouds usually travel at the speed of the winds at corresponding levels. There are, however, some exceptions to the foregoing, namely the so-called " stationary clouds " near a mountain. In reality, the cloud that forms on the windward side owing to condensation by the forced ascent and consequent cooling of the air, dissipates on the leeward side because of evaporation resulting from the descent and consequent warming of the air.

Independent of the general drift of the cloud as a whole, there are considerable turbulent movements within the cloud itself, particularly in the case of cumulonimbus or thunder clouds.

Seasonal distribution of cloud.—The chief features of the seasonal distribution of cloud in India is evident on an examination of the cloudiness at selected stations given in *Table 10*. During the cold season cloudiness is greatest over the Himalayan region and the submontane tracts, and is mainly due to the passage of western depressions across northern India. In the hot season the amount of cloud is largest in the south of the Peninsula, Tenasserim, Bengal and Assam, where the local sea winds are strongest and meet with ranges of hills shortly after their passage inland across the coast. During the south-west monsoon period, cloud formation is determined by the extension of the humid currents and by the various conditions which favour ascensional movement in a humid current, more especially the forced ascent due to the presence of hills or the convergence of two air currents, as for example along the seasonal trough of low pressure. Hence the amount of cloud in this season is greatest in the coast districts, over and near the various mountain ranges and in and around the monsoon trough of low pressure in the Gangetic Plain. Skies are generally free from cloud during this period in Baluchistan, Persia and the Persian Gulf, which are outside the region served by the south-west monsoon current.

In the retreating monsoon period, the area of greatest cloudiness is confined to south Madras and Tenasserim, the skies being generally clear in north and central India.

TABLE 10.

MEAN CLOUDINESS AT 8 HOURS.

Stations.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Persian Gulf, Mekran Coast and North-West India.													
Bahrein .	2·9	2·2	2·1	1·5	1·2	0·3	0·3	0·6	0·3	0·5	1·1	2·7	1·3
Bushire .	4·5	4·0	4·1	3·3	2·2	0·2	0·8	1·0	0·6	1·0	2·6	4·7	2·4
Jask. . .	2·8	2·3	2·1	1·9	0·9	1·1	3·0	2·8	2·1	0·5	1·0	2·3	1·9
Pasni . .	2·6	2·7	2·3	1·9	2·5	3·6	5·5	6·8	4·1	1·8	1·0	1·9	3·1
Karachi (Manora)	2·6	2·3	2·4	2·6	3·3	5·4	7·3	7·5	4·8	1·6	1·1	1·9	3·6
Jacobabad .	2·0	2·7	2·5	1·8	0·7	0·8	2·1	2·0	0·6	0·4	1·1	2·2	1·7
Quetta. .	3·9	3·7	3·5	2·5	1·0	0·6	1·3	1·3	0·4	0·4	1·5	3·1	1·9
Peshawar .	4·4	4·3	4·4	3·6	2·1	1·8	2·9	3·2	1·4	1·1	2·0	3·7	2·9
Srinagar .	7·9	7·8	6·3	5·2	3·4	2·8	4·1	4·5	3·2	2·1	2·6	5·8	4·6
Lahore .	3·7	3·6	3·5	2·7	1·7	2·2	3·8	3·7	1·7	0·6	1·3	2·7	2·6
Simla . .	4·6	4·4	4·2	3·4	2·6	4·4	7·9	8·0	4·3	1·0	1·6	3·4	4·1
Delhi . .	3·2	3·0	2·5	1·8	1·9	3·8	6·4	6·0	3·0	0·8	1·0	2·0	2·9
Agra .. .	2·6	2·4	2·2	1·6	1·4	3·3	6·3	6·5	3·6	0·9	0·8	1·4	2·7
Jodhpur .	3·0	2·7	2·7	2·0	1·3	3·4	6·8	7·2	4·1	1·3	1·1	2·1	3·1

TABLE 10—*contd.*

MEAN CLOUDINESS AT 8 HOURS—*contd.*

Stations.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
North-East India and Burma.													
Allahabad .	2·8	2·8	2·3	1·9	1·9	5·0	8·0	8·6	5·5	2·0	1·3	1·6	3·6
Patna .	2·0	2·4	1·8	1·5	2·2	5·7	8·3	8·5	5·9	2·3	1·1	1·0	3·6
Gaya .	2·2	2·4	2·0	1·8	2·4	4·9	6·5	6·6	4·7	2·5	1·5	1·4	3·2
Sambalpur .	2·2	2·4	2·0	2·5	3·2	6·8	8·3	8·3	6·1	3·1	2·3	1·7	4·1
Calcutta .	2·0	2·6	2·9	3·6	4·7	7·4	8·6	8·5	6·9	3·6	2·0	1·5	4·5
Narayanganj.	2·2	3·0	4·5	5·6	5·9	8·2	8·5	8·6	7·5	4·3	2·5	2·0	5·2
Tezpur. .	2·9	3·6	3·3	5·3	6·0	7·4	8·1	7·8	6·8	4·4	2·6	2·3	5·0
Mandalay .	1·9	1·5	1·8	2·3	4·1	5·6	6·1	6·2	5·5	4·0	3·5	2·6	3·8
Chittagong .	1·6	2·2	3·2	4·5	5·5	7·4	7·8	7·7	6·9	4·4	3·1	1·9	4·7
Akyab. .	1·5	1·5	2·7	4·1	5·9	8·4	8·8	8·7	7·3	5·4	3·7	2·3	5·0
Rangoon .	3·0	2·8	3·6	4·1	7·3	8·9	9·2	9·1	8·6	6·5	4·5	3·4	5·9
Victoria Point	4·0	3·6	4·6	5·6	6·8	7·6	7·7	7·4	7·3	6·7	5·9	5·5	6·1
Central Parts.													
Ajmer .	2·5	2·2	2·1	1·8	1·2	3·1	5·7	6·2	3·5	1·2	1·0	1·7	2·7
Kotah. .	1·9	1·9	1·6	1·5	1·1	2·9	5·8	6·0	3·3	1·3	0·9	1·3	2·5
Jubbulpore .	2·0	2·0	1·6	1·5	1·5	4·8	8·1	8·4	5·3	2·0	1·3	1·3	3·3
Nagpur .	1·6	2·0	1·7	2·2	2·5	6·0	7·9	8·1	5·7	2·8	2·1	1·9	3·7
Chanda .	1·9	1·8	1·5	2·1	2·6	6·1	7·7	7·7	5·8	3·0	2·2	1·7	3·7
Raipur .	1·8	2·0	1·7	2·2	2·7	6·1	7·8	7·9	5·7	3·0	2·0	1·6	3·7
Peninsula.													
Ahmedabad .	1·6	1·6	1·6	1·5	2·4	6·2	7·9	7·9	5·2	1·6	1·2	1·3	3·3
Bombay .	1·5	1·3	1·8	3·1	4·3	7·5	8·8	8·8	7·2	3·9	2·0	1·6	4·3
Poona .	1·3	0·9	1·0	1·4	2·2	6·5	8·0	7·6	6·4	3·6	1·9	1·5	3·5
Hyderabad (Dn.)	2·5	2·0	1·5	2·2	3·6	6·6	7·8	7·5	6·4	4·0	3·3	2·2	4 1
Bangalore .	3·4	1·9	1·3	2·8	4·4	7·5	8·6	8·7	8·0	6·2	5·1	4·1	5·2
Vizagapatam (Waltair).	2·7	2·9	2·9	4·3	5·7	7·8	8·3	7·9	7·1	5·1	4·4	3·3	5·2
Madras .	3·4	2·5	2·2	4·0	3·8	5·7	6·9	6·6	6·2	5·2	5·5	4·7	4·7
Negapatam .	5·2	4·4	4·1	4·3	4·2	4·6	5·2	5·3	5·1	6·1	6·5	6·3	5·1
Karwar .	1·0	1·0	1·5	2·8	4·0	7·3	7·7	7·4	6·0	4·3	2·6	1·4	3·9
Trivandrum .	3·2	2·6	2·6	4·6	6·4	8·4	8·5	7·9	7·1	6·9	6·1	4·5	5·7
Colombo .	4·7	4·2	4·3	5·7	7·1	7·8	7·4	7·1	7·0	6·9	6·1	5·3	6·1

CHAPTER 6.

VISIBILITY AND FOG.

Visibility : definition.—Visibility is defined to be the greatest distance from an observation point at which prominent objects such as trees, buildings, etc. can be seen and identified by the unaided eye. The scale adopted by the International Commission for Air Navigation for the observation and reporting of horizontal visibility is given below.

Visibility Scale.

Scale.	Specification.	Descriptive terms.
0	Objects not visible at 55 yds. (50 Metres)	Dense fog or dense dust-storm.
1	,, ,, ,, 220 ,, (200 ,,)	Thick fog or thick dust-storm.
2	,, ,, ,, 550 ,, (500 ,,)	Moderate fog and dust-storm. or thick haze.
3	,, ,, ,, 1,100 ,, (1,000 ,,)	Slight fog and dust-storm, or moderate haze.
4	,, ,, ,, 1¼miles (2,000 ,,)	Mist or slight haze.
5	,, ,, ,, 2½ ,, (4,000 ,,)	Poor visibility.
6	,, ,, ,, 6¼ ,, (10,000 ,,)	Fair visibility.
7	,, ,, ,, 12½ ,, (20,000 ,,)	Good visibility.
8	,, ,, ,, 31 ,, (50,000 ,,)	Very good visibility.
9	Objects visible at 31 miles (50,000 m.) or more	Excellent visibility.

Visibility depends chiefly upon the amount of liquid or solid particles held in suspension by the air in the form of fog, drizzle and rain, or dust and smoke.

Fog.—Fog like cloud is caused by the cooling of moist air until condensation takes place. On land this happens most frequently in autumn and winter through cooling of the ground by radiation on calm clear nights. An almost invariable accompaniment of fogs, at least of dense ones, is an " inversion " in temperature. By this is meant an increase in temperature with height above the ground instead of the normal decrease. This inversion acts as a barrier to the extension of fog particles upwards.

Fogs at sea, unlike land fogs, are characteristic of spring and summer, and are usually formed by the passage of warm land air over a relatively cold sea. The drifting of fog from land in autumn and winter is also an important factor in the occurrence of fog at sea. Coastal fogs may partake of the nature of either land fog or sea fog.

High level country may experience fog at all seasons due to drifting of low cloud. The so-called " mountain fogs " are strictly low clouds which envelop the higher points of a mountanous tract.

The height to which an ordinary fog extends varies considerably. On land, the height ranges from a few metres for the shallowest of radiation fogs to probably 300 metres or so for heavy ones. The accumulation of radiation fog in valleys under suitable conditions of air-drainage may extend to a few hundred metres. Sea fogs are sometimes so shallow that the mastheads of ships protrude above them, but they occasionally attain to heights of 300 to 600 metres.

Land fogs usually form in the early morning hours and disappear in the middle of the forenoon, the average duration being 4 to 5 hours. In very exceptional cases, however, the conditions favouring fog may be persistent day and night for a number of days, with a temporary dissipation in the mid-day. Sea fogs usually last longer than land fogs. *Table 11* gives the number of days on which fog may be expected at some of the important stations in India.

TABLE 11.

DAYS WITH FOG.

Stations.	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Peshawar	0·1	0·1	0	0	0	0	0	0	0	0	0	0·1	0·3
Rawalpindi	0·7	0·5	0·2	0	0	0	0	0	0	0	0	0·5	1·9
Srinagar	1·9	2·7	0·5	0	0	0·1	0	0	0·1	0.3	1·2	1·2	8·0
Lahore.	0·9	0·2	0·1	0	0	0	0	0	0	0	0	0·5	1·7
Simla	0·2	0·1	0·3	0·3	0·2	1·3	4·3	4·1	2·5	0.3	0·1	0·1	13·8
Dehra-Dun	0·5	0·3	0·1	0	0·1	0	0	0·4	1·0	0.2	0·1	0	2·7
Agra	1·7	0·5	0·1	0·1	0·4	0·1	0·1	0	0	0.1	0·3	0·7	4·1
Mount Abu	0·3	0·5	0·5	0·3	0·6	6·1	17·3	19·3	6·1	0.3	0·1	0	51·4
Pachmarhi	0.2	0·1	0·1	0	0	0·3	1·7	1·9	2·3	0.4	0·8	0·1	7·9
Nagpur	0·3	0·1	0·1	0	0	0	0	0	0·1	0.1	0·1	0·1	0·9
Calcutta	5·9	4·6	1·9	0·3	0·1	0	0	0	0	0.3	1·0	1·5	15·6
Darjiling	3·1	3·5	2·8	5·7	9·1	15·1	16·2	17·1	12·9	4.1	1·9	2·4	93·9
Shillong	0·3	0·7	0·1	0·1	0·1	0·4	0·2	0·4	0·5	0.4	0·3	0·1	3·6
Maymyo	0·7	0·6	0·7	0·3	1·2	1·1	0·5	0·6	0·7	0.6	0·4	1·3	8·7
Rangoon	3·9	6·0	5·7	0·5	0·2	0·1	0	0·1	0·1	0.4	0·5	0·9	19·4
Bombay	0	0·1	0	0	0	0	0	0	0	0	0	0·1	0·1
Bangalore	4·3	1·5	0·5	0	0·1	0·3	0·3	1·3	1·7	1.9	1·4	4·2	17·5
Madras	0·2	0·3	0·	0·1	0	0	0	0	0	0	0	0·1	0·7
Kodaikanal	4·9	1·3	0·5	0·4	0·4	0·3	1·1	0·9	1·1	3·6	8.1	7·3	29·9

Drizzle and rain.—Fog is not the only obstruction to vision of the moisture class. Rain or drizzle constitutes another source of hindrance to vision. As a rule, with both liquid and solid particles, the finer and more dense the particles the worse is the visibility. A light shower of rain with large drops does not hinder vision as much as rainfall in the form of fine drizzle, the density of water in air being the same in the two cases. This should not, however, be construed to mean that the loss of visibility in continuous heavy rain is any less serious. In fact, the rain squalls and the torrential rain associated with cyclonic storms or strong bursts of south-west monsoon, constitute one of the most serious obstructions to vision. Sailors describe their experiences on such occasions in terms such as " blinding rain coming down in continuous torrents ", or " in one solid body ", or " squalls accompanied with such blinding rain that it was an impossibility to see the forepart of the ship ".

Dust.—During the dry hot weather (March—June) dust or sandstorms are fairly frequent in the arid regions of north-west India. In a dust-squall associated with a dry thunderstorm the dust is sometimes lifted several hundred metres and becomes dense enough to prevent safe landings and take-offs. Duststorms are most frequent in the afternoon, but they may occur at any hour of the day. Dust raised by high winds often remains suspended in the air in the form of a dusthaze for a considerable time. Under certain conditions a dusthaze restricting the visibility to less than hundred metres may persist in the atmosphere for more than 24 hours.

Smoke.—In winter, large cities as a rule are surrounded by areas of low visibility resulting from pollution of the air by smoke and other products of combustion. Smoke-haze is most frequent in the night and early morning. A mixture of fog and smoke is a fairly common occurrence in the morning hours in industrial cities.

Vertical visibility.—The visibility usually observed and reported is the visibility measured in a horizontal direction near the ground. Vertical visibility cannot, as a rule, be estimated from the ground upwards. It should be noted that ground visibility is not always a good criterion of the visibility experienced at ordinary flying levels. For example clouds, even in the incipient form, often greatly diminish visibility from the air.

It sometimes happens that an aeroplane can be seen from the ground when the ground cannot be seen from the plane. This condition arises when there is a shallow layer of mist or haze on the ground, while the plane is in full sunshine. The top of this layer is called the " dust horizon ". The effect of the shallow haze is similar to that of a lace window-curtain, which enables the occupants of a room to see out while the interior cannot be seen from the outside.

If there is a marked temperature inversion during the summer, particularly in the coastal regions, and if a pilot is flying above the inversion surface, he may find his earthward visibility affected owing to a peculiar optical effect giving the appearance of a layer of mist or fog over the ground, except that directly below the plane objects can be faintly seen. From a point near the level where the inversion begins, the top of the cool moist layer has the appearance of a line on the horizon, above which an apparent layer of exceptionally clear air prevails. The phenomenon disappears at night.

Frequencies of horizontal visibility.—In *Table 12* have been given the percentage frequencies of horizontal visibility in the morning as well as afternoon at the important stations along the various air-routes for the following groups of months :—

(1) January and February.
(2) April and May.
(3) July and August.
(4) October and November.

They represent all the different types of variations in the horizontal visibility that may be expected in the different seasons.

TABLE 12.

PERCENTAGE FREQUENCIES OF HORIZONTAL VISIBILITY.

Stations.	Morning.										Afternoon.										Morning.										Afternoon.									
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
	JANUARY—FEBRUARY.																				APRIL—MAY.																			
Bahrein	1	1	1	1	1	20	24	50	1	...	...	...	1	...	1	17	14	61	6	...	...	1	1	2	3	19	21	50	3	...	...	...	...	1	2	17	10	58	12	...
Gwador	...	1	1	2	2	8	22	28	29	7	...	1	1	4	14	4	19	25	28	4	1	1	...	1	4	23	54	15	1	...	...	...	1	1	5	24	50	18	1	...
Drigh Road (Karachi.)	1	1	1	1	1	3	13	28	42	9	...	...	...	...	1	1	4	24	61	9	...	...	...	1	2	5	22	57	12	1	1	1	...	1	1	3	22	57	13	1
Ajmer	...	...	...	1	7	14	45	29	4	...	...	...	...	...	...	...	2	85	13	...	...	...	1	1	2	12	30	41	9	4	...	...	...	...	1	4	10	76	9	...
Delhi	1	3	2	6	25	41	9	9	4	...	...	...	...	...	1	9	34	31	25	...	...	...	...	2	7	45	21	24	1	...	...	...	...	1	2	7	19	45	26	...
Agra	1	1	1	2	10	28	45	12	...	...	...	...	...	...	...	1	43	56	...	...	...	...	...	1	3	11	50	34	1	...	...	...	...	1	1	7	32	54	5	...
Allahabad	1	1	1	5	11	27	52	2	...	...	...	...	...	...	...	4	67	29	...	...	...	...	...	1	1	13	67	18	...	...	...	...	...	...	...	5	56	39	...	...
Jubbulpore	...	...	1	1	1	1	9	87	...	...	...	...	...	...	...	...	1	94	5	...	...	...	...	...	...	1	...	94	5	...	...	...	...	...	1	1	2	80	15	1
Patna	1	2	1	7	11	38	27	13	...	...	...	...	...	...	...	2	15	83	...	...	...	...	...	1	1	21	49	28	...	...	...	...	...	...	1	6	32	61	...	...
Calcutta	17	23	17	19	16	7	1	...	...	...	...	1	14	12	10	22	41	...	...	...	...	3	16	20	25	15	21	...	...	...	...	...	10	6	21	27	36	...	...	...
Narayanganj	1	2	3	9	2	8	75	...	...	...	...	...	...	...	...	...	94	6	...	...	...	...	...	...	...	1	84	15	...	...	...	...	...	...	...	1	72	27	...	...
Akyab	...	1	1	3	7	22	46	20	...	...	...	...	...	1	24	11	37	27	...	...	...	1	...	3	2	13	32	49	...	...	...	1	1	2	3	35	39	19	...	...
Rangoon	...	1	2	1	20	40	23	13	...	...	...	...	...	...	38	50	12	...	...	...	...	...	...	1	5	48	16	30	...	...	...	...	...	...	...	10	89	1	...	...
	JULY—AUGUST.																				OCTOBER—NOVEMBER.																			
Bahrein	...	2	3	5	8	17	30	29	6	...	...	1	1	2	2	8	29	45	10	2	...	1	...	1	1	10	23	47	4	3	...	...	...	...	...	9	18	62	9	2
Gwador	...	...	...	1	9	57	29	3	1	...	...	...	...	2	8	55	29	3	2	1	1	...	2	1	4	6	20	36	24	6	5	1	1	4	7	6	14	30	28	4
Drigh Road (Karachi.)	...	...	...	...	1	15	46	35	3	...	...	...	...	...	2	10	50	33	5	...	...	1	1	1	1	1	3	36	46	10	...	...	...	...	1	1	4	33	55	6
Ajmer	...	...	...	...	1	7	22	44	10	16	...	...	...	...	...	2	14	68	16	...	...	...	...	1	...	10	34	45	6	4	...	...	...	...	...	...	1	98	1	...
Delhi	...	...	...	1	10	39	22	21	7	...	...	...	...	1	2	6	26	22	43	...	...	1	1	4	9	39	11	26	9	...	...	...	...	1	...	8	20	38	33	...
Agra	...	...	...	1	2	2	29	65	1	...	...	...	...	...	1	2	27	70	...	...	...	...	...	1	6	21	28	44	...	...	...	...	...	...	...	1	30	69	...	...
Allahabad	...	...	...	...	1	6	37	56	...	...	...	...	...	...	...	5	45	50	...	...	...	...	...	1	2	17	44	36	...	...	...	...	...	...	...	1	45	54	...	...
Jubbulpore	...	...	...	...	1	7	21	69	2	...	...	...	...	1	1	6	12	75	5	...	...	...	...	1	...	1	2	96	...	...	...	...	...	...	...	1	2	96	1	...
Patna	...	1	2	11	3	10	17	56	...	...	...	...	...	...	...	1	7	92	...	...	...	...	...	1	1	17	42	39	...	...	...	...	...	...	...	1	17	82	...	...
Calcutta	1	8	19	20	19	14	19	...	...	...	...	1	7	17	11	30	34	...	...	...	...	7	23	23	24	17	6	...	...	...	...	3	8	22	16	25	26	...	...	...
Narayanganj	...	...	...	...	...	1	86	13	...	...	...	...	...	...	...	1	77	22	...	...	...	1	...	...	1	...	83	15	...	...	...	...	...	...	...	...	94	6	...	...
Akyab	...	...	4	11	19	25	23	18	...	...	...	...	1	9	16	26	27	21	...	...	...	1	1	2	5	26	16	49	...	...	...	1	2	9	4	3	10	71	...	...
Rangoon	...	...	...	1	6	55	27	11	...	...	...	...	1	1	10	34	48	6	...	..	...	...	...	...	2	40	16	35	7	...	...	...	3	23	44	21	9	...	...	...

TABLE 12.—(*contd.*)

PERCENTAGE FREQUENCIES OF HORIZONTAL VISIBILITY.

Stations.	Morning.										Afternoon.										Morning.										Afternoon.									
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
—	JANUARY—FEBRUARY.																				APRIL—MAY.																			
Ahmedabad	...	...	...	1	40	55	4	...	...	...	...	...	...	...	...	31	69	...	...	...	..	...	...	...	2	30	68	...	...	...	...	...	...	...	1	6	93	...	...	...
Poona	...	...	...	...	4	11	29	34	20	2	...	...	...	...	...	...	...	...	77	23	...	...	...	...	...	1	5	53	29	12	...	...	...	...	...	...	8	37	41	14
Hyderabad (Deccan)	3	...	2	1	13	30	37	14	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	18	49	24	7	...	...	...	...	..	...	...	...	...	...	...
Bangalore	...	1	1	1	18	50	25	3	1	...	...	...	...	...	...	...	49	51	...	...	...	..	...	1	5	37	26	20	10	1	...	...	...	1	1	5	52	30	11	...
Madras	...	...	1	...	2	5	25	60	7	...	...	...	...	...	...	...	...	10	90	...	...	...	...	...	...	2	6	25	67	...	...	...	...	...	...	1	5	19	75	...
Vizagapatam	...	...	...	...	1	...	6	45	48	...	...	...	...	...	...	...	...	33	67	...	...	...	...	1	1	1	6	61	30	...	...	...	...	...	...	1	8	62	29	...
Colombo*	...	...	...	...	...	...	6	10	47	37	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	2	13	9	74	1	...	...	...	...	...	...	...	...	...	...
Quetta	...	...	1	2	2	3	9	35	48	...	...	...	1	1	1	5	4	11	60	17	...	...	...	1	2	2	11	38	46	...	...	...	1	...	2	3	6	19	55	14
Peshawar	1	1	...	1	1	2	2	8	9	75	...	...	...	...	1	1	3	5	15	75	...	...	...	1	1	...	2	7	25	64	...	1	...	1	1	1	2	5	31	58
Lahore	..	1	1	6	16	35	25	14	2	...	...	...	...	1	...	9	56	33	1	...	...	...	1	2	6	27	40	20	4	...	...	...	...	1	2	12	48	35	2	...
	July—August.																				October—November.																			
Ahmedabad	...	...	...	1	2	53	44	...	...	...	...	...	...	...	5	25	70	...	...	...	...	...	...	1	16	52	31	...	...	...	...	...	...	...	1	34	65	..	...	...
Poona	...	...	...	1	1	11	52	27	8	...	...	...	...	1	1	7	36	27	25	3	...	...	...	1	2	8	28	38	21	2	...	...	...	...	...	...	1	15	81	3
Hyderabad (Deccan).	...	...	...	...	...	9	51	40	...	...	...	...	...	...	...	...	...	...	...	...	1	...	1	1	1	7	44	45	...	...	...	...	...	...	...	...	...	...	...	...
Bangalore	...	...	...	...	7	39	35	13	5	1	...	...	...	1	6	23	41	22	6	1	...	1	...	1	8	40	29	14	6	1	...	...	...	1	4	19	30	32	14	...
Madras	...	...	...	...	1	1	...	12	86	...	...	...	...	...	1	1	...	20	78	...	...	...	1	1	1	5	6	34	52	...	...	...	...	...	3	2	5	26	64	...
Vizagapatam	...	...	..	...	1	1	11	56	31	...	...	...	...	...	...	1	16	51	32	...	...	...	...	1	1	1	7	55	35	...	...	...	...	...	1	2	7	59	31	...
Colombo*	...	...	...	...	...	1	20	13	66	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7	19	53	21	...	...	...	...	...	...	...	...	...	...
Quetta	...	...	1	2	7	12	18	44	16	...	...	1	...	..	3	9	14	25	45	3	1	...	...	...	1	2	3	61	32	...	...	...	...	...	...	1	1	4	79	15
Peshawar	..	...	...	1	4	8	12	16	25	34	...	1	...	2	1	6	13	13	29	35	...	...	.	...	...	1	2	5	25	67	...	...	...	...	1	1	2	10	51	35
Lahore	..	...	1	1	2	16	33	41	6	...	...	...	...	1	2	9	35	46	7	...	...	...	1	4	15	31	37	12	...	...	...	...	...	...	...	28	63	9	...	...

From 1 year's observations only.

CHAPTER 7.

RAINFALL.

Seasonal distribution.—Rainfall in India may be considered broadly under two main periods, one from December to April of dry weather over most of the country and the other from May to November of wet weather (*Figs. 25-26*).

During the first half of the dry season from December to February, the precipitation is due to the passage of shallow winter depressions across northern India and occurs chiefly in the mountain regions forming the north and north-west border of India and in the adjoining plains. The snowfall is very heavy during this period in the western Himalayas. The precipitation diminishes southwards from the Himalayas across the submontane tracts to only a small amount of rainfall on the plains. The second half of the dry period is the hot weather season from March to May or June. During this period, the rainfall occurs chiefly in association with local thunderstorms and as a rule is very irregularly distributed, being moderate to large in amount only in Malabar, Tenasserim, Bengal and Assam.

The rainfall of the period May to November is due to the invasion of the Indian area by the great oceanic current of the south-west monsoon. As stated earlier, this current usually advances into the Indian Seas in the last week of May or first week of June and begins to give heavy rain on the coastal districts of Burma and Malabar. It extends rapidly across the Bengal and Bombay coasts into the interior and during the next three months gives more or less frequent and general rainfall over the greater part of India. It is significant to note the large concentration of rainfall during this period on and in front of the Western Ghats and the Arakan-Tenasserim hills compared with the relatively small rainfall in the interior of the Peninsula and in central Burma. These are two pronounced examples of the orographic effect of mountain ranges causing excessive rainfall on the windward side and scanty rain on the leeward side. The concentration of rainfall in the Assam hills and north Bengal is also due to orography. The comparatively large rainfall from Bengal to the centre of the country is associated with the passage of depressions forming at the head of Bay of Bengal across this belt. The region which receives least rainfall during this season extends westwards from the south-west Punjab and Sind across Baluchistan. The south-east of Madras also receives very little rain during the rains proper.

In the second half of the wet season from September to November, the rainfall is due to the oceanic current which persists in the Bay of Bengal, after the retreat of the monsoon from northern India. Burma and Bengal receive light to moderate rain during the first half of this period. By the middle of October the current usually ceases to extend far northward, but curves from Burma over the Bay and strikes the Madras coast as an easterly or north-easterly current. Hence the most important rainfall of the retreating oceanic currents is received in south-east Madras and Mysore, the amount being largest on the Coromandel Coast. The rainfall of the period is, therefore, most general in those parts of the south Peninsula where the rainfall in the rains proper is scanty.

Rainy days and frequency of heavy rainfall.—A rainy day is one on which at least a tenth of an inch of rain has fallen. The average monthly and annual rainfall and number of rainy days as well as the frequency of heavy rainfall for the important stations along the air-routes have been given in *Tables 13* and *14*.

Plate 19.

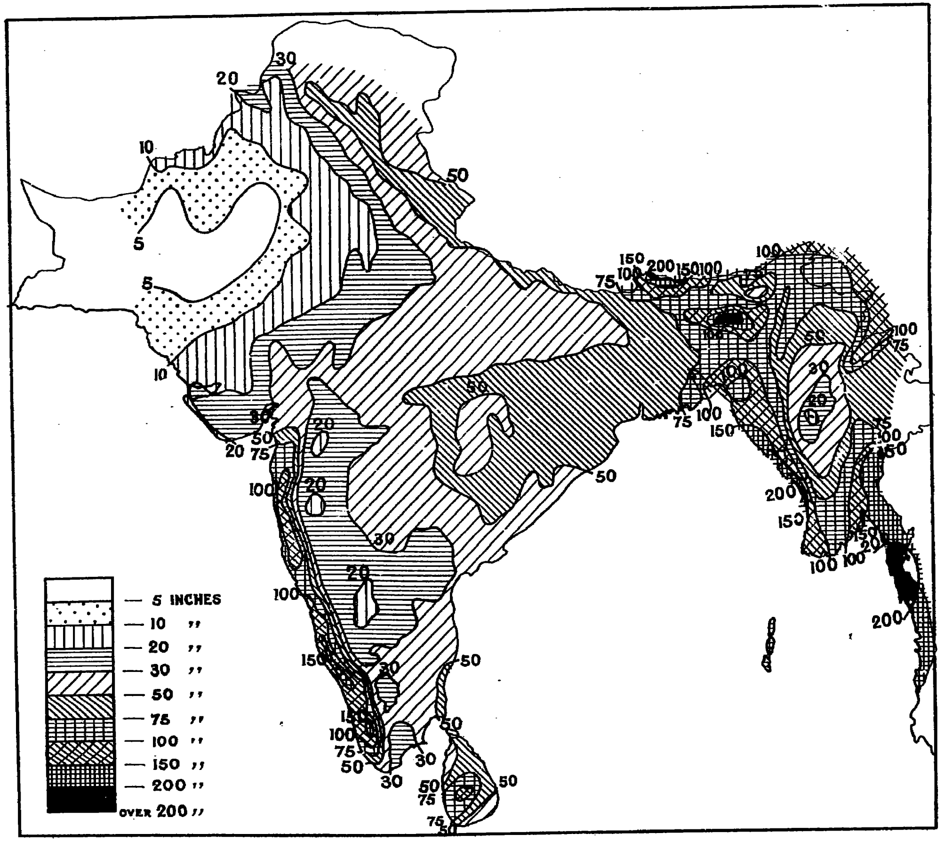


FIG. 25. MEAN ANNUAL RAINFALL (Corrected to 1914.)

(O) G. P. Z. O. Poona, 1935.

Plate 20.

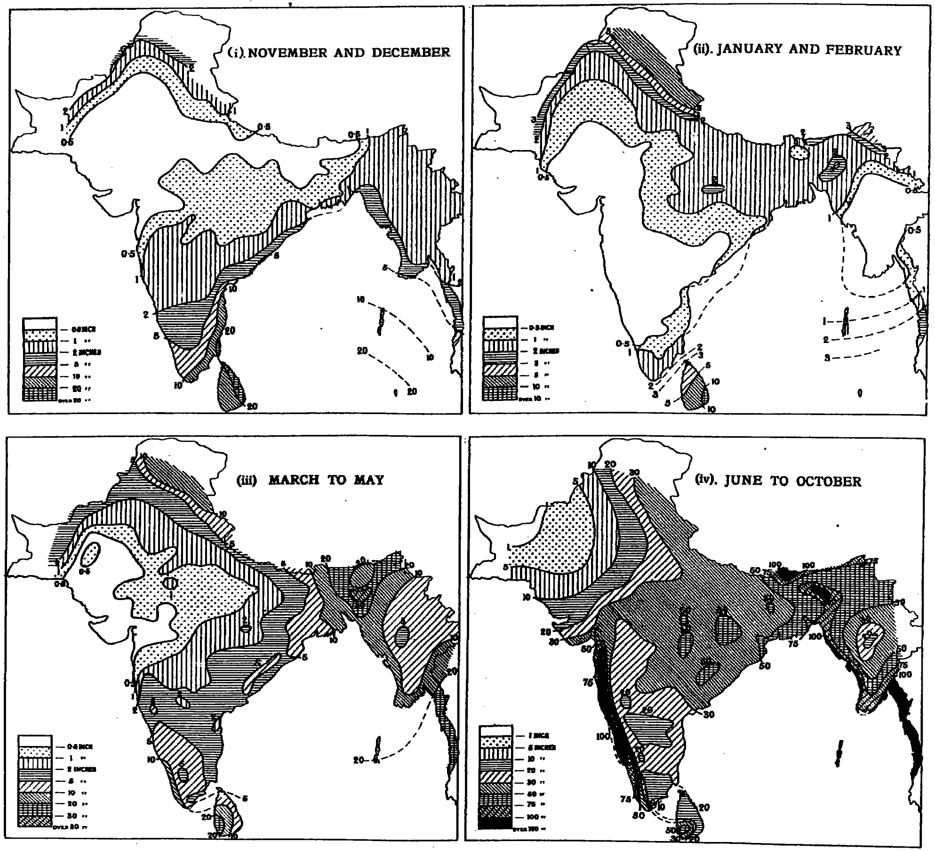


FIG. 26. MEAN SEASONAL RAINFALL.

(0) G.P.Z.O. Poona, 1935.

TABLE 13.

MONTHLY AND ANNUAL RAINFALL AND NO. OF RAINY DAYS.

Normal rainfal in inches printed in ordinary type;

Normals of rainy days printed in heavy type.

Station.	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.
Bahrein	0·41 **1·1**	0·68 **1·6**	0·52 **1·2**	0·23 **0·7**	0·07 **0·2**	0 **0**	0 **0**	0 **0**	0 **0**	0·01 **0·1**	0·24 **0·5**	0·82 **1·6**	2·98 **7·0**
Gwador	1·49 **1·7**	1·74 **2·3**	0·49 **0·8**	0·55 **0·2**	0 **0**	0·06 **0·2**	0·49 **0·8**	0 **0**	0 **0**	0 **0**	0·28 **0·9**	2·97 **2·3**	7·96 **9·0**
Karachi (Drigh Road).	0·09 **0·4**	0.03 **0**	0·03 **0·2**	0·02 **0**	0·26 **0·4**	0·27 **0·2**	8·29 **5·8**	0·97 **1·2**	0·50 **1·0**	0 **0**	0·20 **0·4**	0·13 **0·2**	10·79 **9·8**
Jodhpur	0·14 **0·4**	0·20 **0·6**	0·09 **0·2**	0·15 **0·5**	0·45 **1·1**	1·45 **2·1**	3·69 **4·8**	4·40 **5·3**	2·46 **2·8**	0·36 **0·4**	0·11 **0·2**	0·12 **0·5**	13·62 **18·9**
Delhi	1·04 **2·1**	0·76 **1·6**	0·52 **1·4**	0·39 **0·8**	0·58 **1·8**	2·99 **4·0**	7·53 **8·9**	7·42 **9·2**	4·78 **4·5**	0·32 **0·5**	0·11 **0·3**	0·40 **0·9**	26·84 **36·0**
Agra	0·54 **1·3**	0·48 **1·0**	0·35 **1·0**	0·24 **0·7**	0·47 **1·4**	2·35 **3·8**	9·12 **11·4**	8·15 **10·2**	4·05 **5·4**	0·76 **0·8**	0·12 **0·3**	0.27 **0.7**	26·90 **38·0**
Allahabad	0·76 **1·6**	0·58 **1·5**	0·31 **0·8**	0·15 **0·4**	0·34 **0·9**	4·96 **5·4**	11·71 **13·7**	11·70 **14·0**	5·67 **7·7**	2·32 **1·9**	0·33 **0·6**	0·23 **0·5**	39·06 **49·0**
Jubbulpore	0·80 **1·5**	0·82 **1·7**	0·57 **1·5**	0·25 **0·7**	0·53 **1·3**	7·32 **9·0**	17·62 **17·2**	16·86 **17·4**	7·67 **9·7**	1·81 **2·2**	0·57 **0·9**	0·29 **0·6**	55·11 **63·7**
Patna	0·53 **1·1**	0·71 **1·5**	0·47 **1·1**	0·30 **0·6**	1·67 **2·9**	8·12 **8·1**	11·94 **13·9**	13·55 **13·8**	8·33 **9·2**	2·54 **3·1**	0·28 **0·4**	0·09 **0·3**	48·53 **56·0**
Sambalpur	0·41 **0·8**	0·79 **1·7**	0·94 **1·8**	0·65 **1·6**	1·25 **2·4**	10·92 **11·0**	20·02 **19·4**	19·19 **19·2**	8·51 **11·3**	2·00 **3·4**	0·83 **1·0**	0·22 **0·3**	65·73 **73·9**
Calcutta	0·34 **0·7**	1·10 **1·6**	1·44 **2·4**	1·89 **3·2**	5·75 **7·3**	11·90 **13·3**	12·51 **17·8**	12·69 **18·3**	9·87 **13·2**	4·19 **6·0**	0·66 **1·0**	0·20 **0·4**	62·54 **85·2**
Dacca	0·34 **0·8**	1·25 **1·9**	2·63 **3·6**	5·36 **7·2**	9·75 **11·2**	13·56 **15·3**	12·84 **17·5**	13·14 **17·6**	9·76 **11·8**	4·60 **6·0**	0·84 **1·2**	0·17 **0·4**	74·24 **94·5**
Tezpur	0·53 **1·4**	1·14 **2·8**	2·28 **5·1**	6·19 **11·9**	9·95 **14·3**	12·00 **15·6**	14·43 **17·5**	14·36 **16·3**	8·18 **12·1**	4·21 **6·2**	0·74 **1·4**	0·23 **0·5**	74·24 **105·1**
Bhamo	0·49 **1·2**	0·48 **1·4**	0·75 **2·0**	1·89 **4·8**	6·14 **10·1**	13·88 **18·6**	16·78 **19·7**	15·38 **19·4**	9·89 **12·9**	4·26 **6·7**	1·50 **2·7**	0·57 **1·0**	72·01 **100·5**
Mandalay	0·05 **0·1**	0·08 **0·3**	0·19 **0·5**	1·12 **2·2**	5·85 **7·8**	5·52 **7·3**	3·29 **5·7**	4·59 **7·9**	5·74 **8·6**	4·72 **6·6**	1·63 **3·0**	0·38 **0·8**	33·16 **50·8**
Akyab	0·06 **0·1**	0·15 **0·4**	0·49 **0·7**	2·07 **2·1**	13·95 **10·5**	46·94 **24·3**	54·80 **27·6**	45·19 **26·8**	22·57 **19·1**	10·91 **9·3**	5·48 **3·7**	0·76 **0·9**	203·37 **125·5**
Rangoon	0·21 **0·3**	0·22 **0·3**	0·32 **0·6**	1·63 **1·7**	11·98 **13·6**	18·04 **23·0**	21·42 **25·1**	19·87 **24·1**	15·27 **19·7**	6·91 **10·0**	2·79 **3·3**	0·3 **0·6**	99·03 **122·3**

TABLE 13—(*contd.*)

MONTHLY AND ANNUAL RAINFALL AND NO. OF RAINY DAYS.

Normal rainfall in inches printed in ordinary type.

Normals of rainy days printed in heavy type.

Station.	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.
Tavoy . .	0·20 **0·4**	0·44 **0·8**	1·59 **2·2**	2·63 **3·7**	22·71 **18·3**	44·24 **25·3**	49·22 **26·8**	47·33 **27·3**	33·06 **22·6**	10·66 **12·4**	2·30 **3·9**	0·36 **0·7**	214·74 **144·4**
Victoria Point	0·40 **1·2**	0·75 **1·3**	2·44 **4·2**	4·82 **7·7**	19·74 **19·6**	29·69 **22·4**	30·05 **23·2**	26·18 **22·5**	26·22 **22·2**	17·79 **17·9**	6·36 **10·8**	2·02 **3·7**	166·46 **156·7**
Ahmedabad .	0·02 **0·1**	0·12 **0·3**	0·08 **0·3**	0·03 **0·1**	0·43 **0·7**	4·33 **5·1**	11·23 **11·9**	8·09 **10·7**	3·73 **4·5**	0·59 **0·9**	0·15 **0·4**	0·03 **0**	28·83 **35·0**
Bombay . .	0·10 **0·2**	0·08 **0·2**	0·07 **0·1**	0·05 **0·1**	0·84 **0·8**	18·31 **14·3**	24.26 **21.3**	13·80 **19·2**	10·50 **12·7**	2·16 **2·8**	0·41 **0·7**	0·05 **0·1**	70·63 **72·5**
Poona . .	0·06 **0·2**	0·06 **0·1**	0·06 **0·2**	0·57 **1·3**	1·20 **1·8**	4·77 **7·6**	7·01 **12·3**	3·66 **9·0**	4·84 **7·5**	3·74 **5·2**	0·98 **1·7**	0·16 **0·5**	27·11 **47·4**
Hyderabad (Dn.) (Begumpet).	0·24 **0·4**	0·30 **0·7**	0·72 **1·0**	1·05 **1·9**	1·00 **2·3**	4·59 **6·6**	6·49 **10·4**	6·30 **10·4**	7·04 **9·3**	3·25 **4·5**	1·10 **2·2**	0·19 **0·4**	32·27 **50·1**
Bangalore .	0·26 **0·5**	0·17 **0·3**	0·50 **0·9**	1·33 **2·3**	4·36 **6·8**	2·89 **5·8**	4·18 **8·4**	5·38 **9·6**	6·98 **9·4**	5·90 **8·9**	2·94 **4·7**	0·48 **1·3**	35·37 **58·9**
Madras . .	1·39 **1·7**	0·32 **0·6**	0·19 **0·3**	0·53 **0·7**	1·07 **1·1**	1·89 **3·7**	3·94 **7·0**	4·64 **7·9**	4·99 **7·1**	11·72 **10·5**	14·25 **11·5**	5·81 **5·2**	50·74 **57·3**
Waltair (Vizagapatam).	0·46 **0·5**	0·85 **0·9**	0·30 **0·5**	0·71 **1·6**	1·99 **3·0**	4·86 **6·8**	4·49 **8·4**	5·36 **8·4**	6·52 **8·5**	7·07 **7·3**	3·75 **4·0**	0·73 **1·0**	37·09 **50·9**
Mangalore .	0·06 **0·1**	0·06 **0·1**	0·08 **0·2**	1·28 **2·0**	6·20 **6·6**	36·78 **24·6**	37·11 **27·2**	22·54 **24·8**	10·42 **15·3**	7·53 **10·2**	3·12 **4·7**	0·50 **0·7**	125·68 **116·5**
Trivandrum .	0·74 **1·5**	0·61 **1·1**	1·62 **2·6**	4·47 **6·8**	8·45 **9·9**	13·39 **16·9**	7·41 **13·8**	4·07 **9·2**	4·14 **7·7**	10·58 **12·2**	6·59 **9·5**	2·44 **3·6**	64·51 **94·8**
Quetta .	1·93 **4·7**	1·86 **4·4**	1·88 **5·0**	1·03 **2·9**	0·37 **1·0**	0·15 **0·4**	0·63 **1·3**	0·46 **0·8**	0·07 **0·2**	0·13 **0·3**	0·32 **0·9**	0·92 **2·3**	9·75 **24·2**
Peshawar	1·56 **3·0**	1·35 **3·1**	2·25 **4·4**	1·85 **4·0**	0.82 **2·0**	0·36 **1·0**	1·24 **2·0**	2·24 **2·6**	0·81 **1·6**	0·16 **0·4**	0·28 **0·5**	0·59 **1·3**	13·51 **25·9**
Lahore .	1·05 **2·1**	0·94 **2·2**	0·86 **1·9**	0·54 **1·6**	0·70 **1·4**	1·68 **2·9**	5·48 **5·8**	5·33 **5·8**	2·36 **2·6**	0·25 **0·6**	0·07 **0·2**	0·36 **1·0**	19·62 **28·1**

TABLE 14.

FREQUENCY OF HEAVY RAINFALL (DURING THE 30 YEARS 1891—1920.)

Stations.	3"—5"	5"—7"	7" and above.	Stations.	3"—5"	5"—7"	7" and above.
Karachi (Manora) .	7	5	2				
Jodhpur . . .	11	4	2	Ahmedabad . .	37	2	2
Delhi (Sadar) . .	23	7	1	Bombay . . .	133	37	18
Agra . . .	14	3	1	Poona . . .	14	0	0
Allahabad . . .	35	8	4	Hyderabad (Dn.) (Superintendent Engineer's Office).	20	2	0
Jubbulpore . .	68	10	4				
Patna (Bankipore) .	61	19	6	Bangalore . .	19	1	1
Sambalpur . . .	81	17	5	Madras . . .	43	14	2
Calcutta (Alipore Observatory).	47	13	6	Waltair . . .	34	10	3
Dacca . . .	66	7	9	Mangalore . .	201	22	13
Tezpur . . .	38	9	1	Trivandrum . .	58	10	1
Bhamo . . .	48	3	1				
Mandalay . . .	28	3	0				
Akyab . . .	405	140	76	Quetta . . .	0	0	0
Rangoon . . .	79	9	2	Peshawar . .	5	0	0
Tavoy . . .	411	102	27	Lahore . . .	11	2	3
Victoria Point* . .	179	35	3				

Stations.	*1"—2"*	*2"—3"*	*3" and above.*
Bahrein** . . .	9	1	0
Gwador† . . .	6	6	2

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* (For the years 1894—1923.)

** Based on 18-19 years' data for the periods October 1901 to December 1913 and 4th November 1927 to 31st December 1933.

† Based on 6-7 years data for the period 2nd October 1927 to 31st December 1933.

CHAPTER 8.

WEATHER MAPS.

The weather map consists of a chart on which are plotted simultaneous or very nearly simultaneous observations from a net-work of stations covering a wide area. It affords the best means of finding out the inter-relation of different meteorological elements, the changes which are taking place in them, the positions, movements and intensity of depressions, storms and other types of weather disturbances, and as such, forms the basis of modern forecasting. In accordance with a long established practice, a weather map is prepared each morning in the Meteorological Office at Poona. It is based on observations taken at 8 hrs. *local* mean time at nearly 300 observatories in India, Burma and Ceylon and not on strictly simultaneous observations. Hence this map and similar maps for 8 hrs.*, but for smaller areas, prepared at the forecasting centres at Karachi, Calcutta, Peshawar and Quetta are not synoptic, but nevertheless they are no less useful for deriving conclusions relating to the day to day sequence of weather. Besides the above, evening maps are prepared at Karachi, Calcutta, Peshawar and Quetta and, so far as the Indian area is concerned, these are synoptic, being based on observations taken at 17 hrs. *I. S. T.*

A typical weather map is shown in *Fig. 27*. For the sake of clearness only the wind speed and direction, temperature, visibility, amount of cloud (classified into two types 'low' and 'medium or high') and weather are indicated for each station. The pressures at individual stations have not been represented, but the distribution of pressure is shown by the series of lines called isobars along any one of which the mean sea-level pressure at each place has the same value. For a description of the methods of observations and the instruments in use at the meteorological stations of the India Meteorological Department reference is made to "Instructions to Observers at the Second and Third Class Observatories" issued by the department.

In the weather map in *Fig. 27* (and in that in *Fig. 28*) the wind direction is indicated by arrows flying with the wind, and the wind force, on the Beaufort scale, by the number of feathers. The figure shown above each station indicates mean temperature in degrees Fahrenheit, and the one below indicates visibility. The circle at the end of each arrow indicates amount of cloud (black, low cloud; shaded, high or medium). The weather is represented by the following symbols : q = squall ; d = drizzle ; r = rain ; p = showers ; f = fog ; ∞ = dust haze ; $\underline{\infty}$ = dust fog ; ≡S≡ = dust storm or sand storm ; $\$$ = dust devils seen ; < = distant lightning ; T = thunder, without rain ; Ꞧ = thunderstorm. At coastal stations, the state of the sea is shown by the symbols : Sm = smooth ; Sl = slight ; Mod = moderate ; Ro = rough ; V. Ro. = very rough. Swell is indicated by a wavy line underneath the symbols for sea at coast stations, and along the direction of the swell in the case of ships' observations, the numbers 1 to 3 preceding the line showing the character of the swell—low, moderate or heavy.

It will be seen from this weather map that the conditions were, more or less, undisturbed at 8 hrs. A reference, however, to the map for 17 hrs. (placed

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* The morning observations are taken at 0400 G. M. T. (9·30 hrs. I. S. T.) over the region extending from Long. 50° to 67° E, at 0600 G. M. T. (11·30 I. S. T.) over Iraq, and 0800 hrs. *local* time over Egypt and India, equivalent to about 0600 and 0300 G. M. T. respectively. The evening observations are taken at 1400 G. M. T. (19·30 I. S. T.) over the section from Long. 50° to 67°E, at 12·00 G. M. T. (17-30 I. S. T.) over Iraq and at 11·30 G. M. T. (17 hrs. I. S. T.) over India.

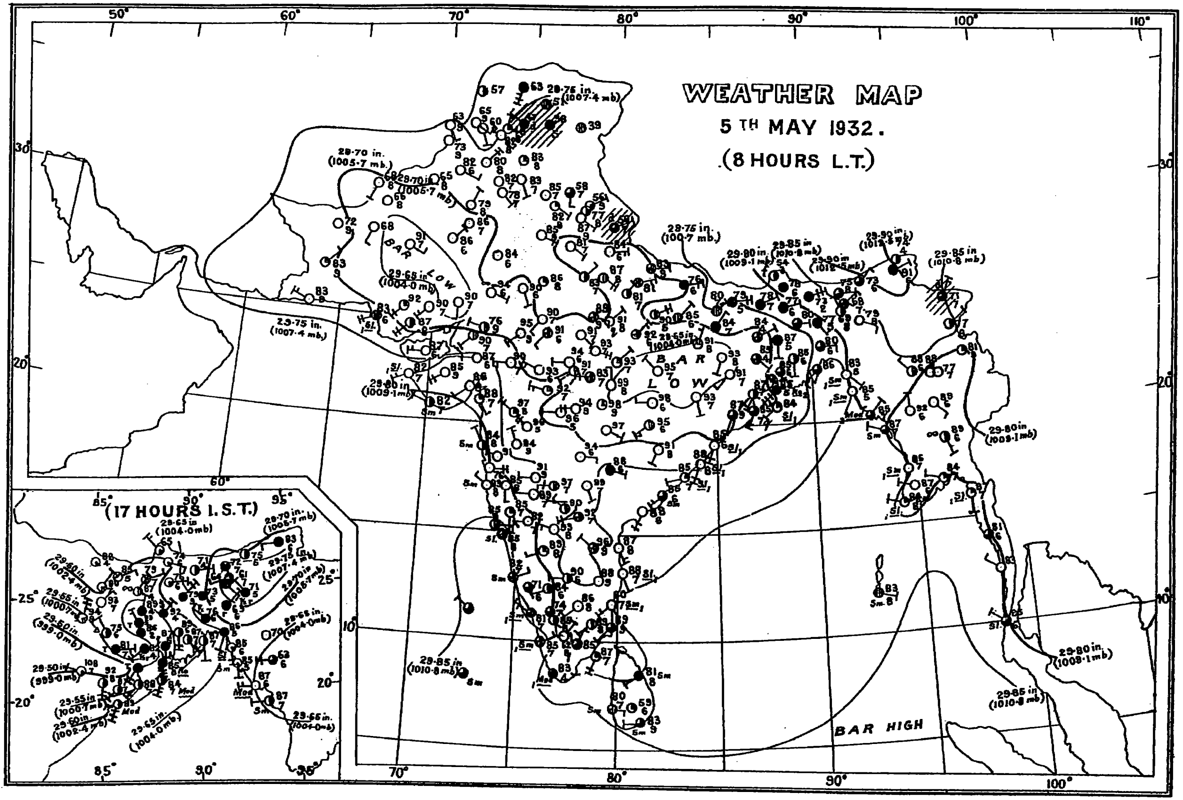

FIG. 27. ***MORNING,*** COMPARATIVELY UNDISTURBED CONDITIONS OVER NORTHEAST INDIA. *Inset*, ***AFTERNOON,*** OCCURRENCE OF THUNDERSTORMS AND NOR'WESTERS.

Plate 22.

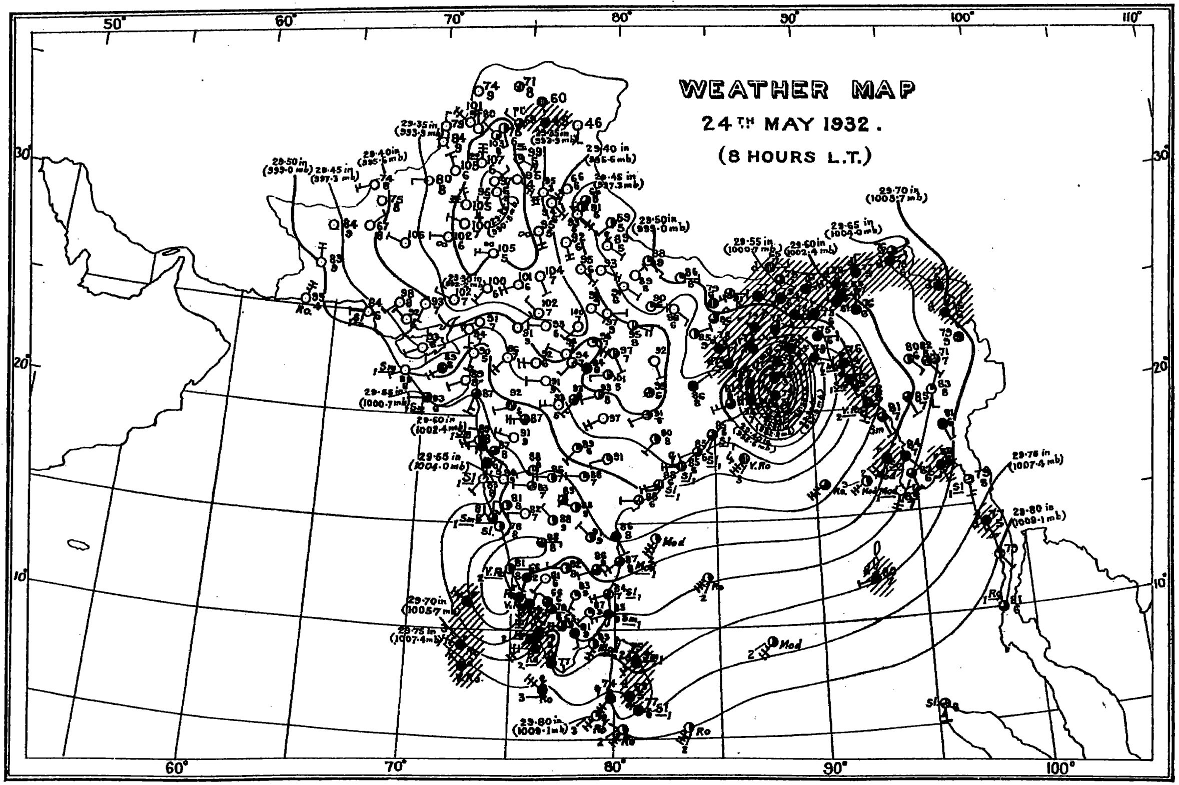

FIG. 28. SEVERE STORM IN BAY OF BENGAL AND MODERATE STORM IN ARABIAN SEA.

(0) G.P.Z.O. Poona, 1935.

as an inset in *Fig. 27*) will show the existence of an area, extending from north Bihar to Assam, of severe thunderstorm activity There is a low pressure area in the Gangetic plain in the map for 8 hrs., which influenced northward movement of the moist air from the head of the Bay of Bengal. At the same time there was downward flow of cold and denser air from the Himalayas into Assam and Bengal. This downward movement was accentuated by the formation of an area of low pressure over Assam in the afternoon which is clearly shown in the 17 hrs. map. This current came face to face with the moist air from the sea and undercut the latter. An unstable vertical gradient of temperature gave rise to conditions favourable for extensive thunderstorms.

In *Fig. 28* has been shown the weather map of 8 hrs. for the 24th May 1932. It shows a severe storm over the head of the Bay of Bengal, which caused highly disturbed weather from the central parts of India up to the extreme limits of Burma. It shows also the simultaneous existence of a moderate storm in the east Arabian Sea.

GIPD—M122DG of Obs. Poona—10-9-36—400.